DOCUMENT RESUME

ED 236 346 CE 037 390

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TITLE Machine Shop Milling Machines. Oklahoma Trade and Industrial Education.

INSTITUTION Oklahoma State Dept. of Vocational and Technical Education, Stillwater. Curriculum and Instructional Materials Center.

PUB DATE 83

NOTE 293p.

AVAILABLE FROM Curriculum and Instructional Materials Center, Oklahoma Dept. of Vocational and Technical Education, 1515 W. Sixth Avenue, Stillwater, OK 74074 (Teacher Edition: In-State--$11.00, Out-of-State--$22.00; Student Edition: In-State--$10.00, Out-of-State--$20.00).

PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.

DESCRIPTORS Adult Education; Behavioral Objectives; Competency Based Education; Curriculum Guides; Learning Activities; *Machine Tool Operators; *Machine Tools; Postsecondary Education; Safety; Secondary Education; Tests; *Trade and Industrial Education; Transparencies; Units of Study

ABSTRACT

This curriculum guide provides instructional materials designed to equip students with basic knowledge and skills that will enable them to enter the machine trades at the machine-operator level. The curriculum is designed for use in full-time secondary and postsecondary classes and part-time adult classes. It can also be adapted to open-entry, open-exit programs. Three instructional units are included, each consisting of eight basic components: performance objectives, teacher activities, information sheets (content essential for meeting the cognitive objective), assignment sheets (applications of knowledge that are prerequisites to skill development), job sheets (procedures to complete a manipulative or psychomotor skill), transparency masters, tests, and test and assignment sheet answers. The units cover (1) identification of parts and attachments of vertical and horizontal milling machines, identification of work-holding devices, safety rules, and performance of general maintenance; (2) set up and operation of a horizontal mill; and (3) set up and operation of a vertical mill. (YLB)

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ED236346

Machine Shop
Milling Machines

OKLAHOMA TRADE AND INDUSTRIAL EDUCATION

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State Department of Vocational and Technical Education
Stillwater, Oklahoma 74074

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FOREWORD

In Oklahoma, vocational educators have a basic belief that quality vocational programs require the use of sound instructional materials. It is this belief that prompted the Oklahoma State Department of Vocational and Technical Education, Curriculum and Instructional Materials Center to develop a curriculum tailored to provide high-quality and uniform training materials for the machinist trade. *Machine Shop Milling Machines* is the third in a series of machine shop curriculum manuals to be published. The first manual, *Machine Shop I,* provides information basic to the machinist trade. *Machine Shop Lathes*, the second volume, is designed to allow the student to specialize in lathe and shaper operations. This third publication in the series concentrates on milling machine operations for both vertical and horizontal milling.

Industry representatives, classroom teachers, and technical specialists collaborated closely to produce materials that will provide each student with information and practical learning experiences directly applicable to the machinist trade. Whether the students are just entering the trade, seasoned machinists upgrading skills, or skilled machinists reviewing procedures and using these materials as reference, they can appreciate the expertise of all those who created *Machine Shop Milling Machines*.

The information in *Machine Shop Milling Machines* should be adapted, personalized, and localized so that this publication will become a vital part of the teaching/learning process. It is our sincere hope that *Machine Shop Milling Machines* and the other manuals in this series will contribute to the development of a competent, safety-conscious work force in the machine shop trade.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
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PREFACE

The purpose of *Machine Shop Milling Machines* is to equip students with basic knowledge and skills that will enable them to enter the machine trade at the machine-operator level.

This curriculum has been designed so that it may be used in full-time secondary and post-secondary classes, as well as part-time adult classes. It can also be adapted to open-entry, open-exit programs so that each student may progress at his or her own pace.

The assignment sheets and job sheets are the chief strengths of this volume. They are directly related to the lesson and provide for appropriate practice with pencil and paper and actual hands-on jobs using the machinery of the trade. The material is competency based in that the objectives of each unit are measurable to a minimum standard of acceptance.

Machine Shop Milling Machines should supplement *Machine Shop I,* but the subject material in the manual is not necessarily arranged in the order of instruction. It is recommended that the instructor arrange the units in this volume to meet individual teaching needs. All or part of a unit may be taught at a given time.

A skilled instructor who can supplement, personalize, and localize this material will go a long way toward helping the learner advance in the machine trade, which is changing at a fantastic rate. These changes have created a great demand for workers with job-ready skills.

James Dunn, Trade and Industrial
Curriculum Specialist

ACKNOWLEDGEMENTS

Planning and Reviewing Committee

I am indeed grateful for the generous contribution of time, expertise, and cooperation given by committee members and the schools or industries they represent.

Special thanks to Mercury Marine; Kobe, Inc.; and Halliburton Services for releasing employees to serve on the committee. *Machine Shop Milling Machines* would not have become a reality without the combined efforts of the following people:

Ed Glasgow — Kobe, Inc., Oklahoma City, Oklahoma
Mitchell Slemp — Mid-America AVTS, Wayne, Oklahoma
Wesley Taylor — Caddo-Kiowa AVTS, Fort Cobb, Oklahoma
Eldon Richey — O.T. Autry AVTS, Enid, Oklahoma
Ralph Moore — Tulsa AVTS at Peoria, Tulsa, Oklahoma
Tom Fite — Mercury Marine, Stillwater, Oklahoma
Kenneth Morgan — Halliburton Services, Duncan, Oklahoma
Clyde Knight — Oklahoma State University, Stillwater, Oklahoma
Bill Hill — State Department of Vocational and Technical Education, Stillwater, Oklahoma
Ken Hulsizer — State Department of Vocational and Technical Education, Stillwater, Oklahoma
James Sharpton — State Department of Vocational and Technical Education, Stillwater, Oklahoma

I would also like to express my appreciation to the following companies for granting permissions for many of the illustrations used in this manual.

Bridgeport Machines, Bridgeport, Connecticut
Cincinatti Milacron, Inc., Cincinnati, Ohio
Moore Special Tools Co., Inc., Brideport, Connecticut
J. Parkinson and Son, Ltd., Yorkshire, England

Deep appreciation is expressed to my co-workers Joyce Sawatzky and Robert Hilley, who patiently trained and assisted me during the development of this curriculum. Sincere appreciation is extended to Bob Patton for giving me the opportunity to write this curriculum and for providing superior leadership during the development and publication of this manual. A great deal of the credit for the readability and clarity of this material goes to the CIMC editing staff under Terra McCluskey. Their help and guidance, their attention to detail, and their concern for a quality product were invaluable in completing this project. My gratitude goes to Terri Perry, Susan Walker, Jerry Weir, Sue Buck, and Barbi Harrison.

Special recognition goes to staff members from the Curriculum and Instructional Materials Center and the Graphics Division of the State Department of Vocational and Technical Education for their services offered during the development and publication of this manual. Most notably, recognition goes to Dana Welborne, who provided many of the excellent illustrations used to supplement the instructional materials, and the members of the Communications Center, who, under the supervision of Jenny Fowler, typed and typeset the many drafts and revisions required during development. Those most involved in the typing for this volume include Dona Landreth, Rose Primeaux, Gari Sha Robinson, and Joanne Voigt. Finally, the services of the Print Shop, under Noel Wilcoxson, produced the quality appearance of this material.

USE OF THIS PUBLICATION

Instructional Units

Machine Shop Milling Machines includes three instructional units. A standard format was established in 1970 for the development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, and job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
  1. Supplies and equipment needed
  2. Amount of practice needed
  3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units so that supplemental materials can be obtained, audiovisual materials prepared, and outside resources contacted. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class' attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Transparencies should be made and placed in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomoter skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test — 85 percent in most units — may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each question. The final unit grade should be obtained by using the paper/pencil score along with teacher evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Machine Shop Milling Machines* has been abbreviated MM. The units are then numbered consecutively. An example of a page number is MM-1. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder for the units. This is more convenient for taking the materials home to study. Upon completion, each unit is placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

Student materials should be provided for each student for best results. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

INTRODUCTION TO MILLING MACHINES
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify parts and attachments of vertical and horizontal milling machines, identify work-holding devices, state safety rules, and perform general maintenance. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with milling machines to their correct definitions.
2. Name types of milling machines.
3. Identify major parts of the horizontal knee-and-column mill.
4. Match specific parts of the horizontal mill to their correct uses.
5. Identify major parts of the turret mill.
6. Match specific parts of the turret mill to their correct uses.
7. Label work-holding devices.
8. Identify cutting tools.
9. Identify toolholders for cutting tools.
10. Match attachments to their correct uses.
11. State rules for milling machine safety.
12. Identify the parts of the indexing or dividing head.
13. Match parts of the indexing or dividing head to their correct descriptions or functions.
14. List operations performed on the dividing or indexing head.
15. Calculate direct and simple indexing.
16. Select from a list reasons for using cutting fluids.
17. List the basic groups of cutting fluids.

OBJECTIVE SHEET

18. Match coolant application methods to their correct descriptions.
19. Identify coolant application methods.
20. Distinguish among causes of cutter failure and finish problems.
21. Calculate machine speed and feed rates.
22. Complete milling machine safety test.
23. Demonstrate the ability to
    a. Clean and lubricate a horizontal mill.
    b. Clean and lubricate a vertical mill.

INTRODUCTION TO MILLING MACHINES
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

- A. Order wall charts to use when discussing milling machine parts and attachments. Charts can be obtained from Bridgeport Machines, 500 Lindley Street, Bridgeport, Connecticut 06606.
- B. Make transparencies.
- C. Provide students with objective sheet.
- D. Provide students with information, assignment, and job sheets.
- E. Discuss unit and specific objectives.
- F. Discuss information and assignment sheets.
- G. Demonstrate and discuss procedures outlined in job sheets.
- H. Provide students with operator's manuals for the machines they will be using.
- I. Display available cutters.
- J. Stress any special safety rules not covered by safety test.
- K. Give test.
- L. Reteach and retest if necessary.

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
    1. TM #1 — Horizontal Mill
    2. TM #2 — Turret Mill
    3. TM #3 — Vertical Mill
    4. TM #4 — Tracer or Duplicating Mill
    5. TM #5 — Bed-Type Manufacturing Mill

SUGGESTED ACTIVITIES

6. TM #6 — Precision Jig Bore
7. TM #7 — Computerized Mill
8. TM #8 — Major Parts of the Horizontal Mill
9. TM #9 — Parts of a Horizontal Mill Column
10. TM #10 — Parts of a Horizontal Mill Knee
11. TM #11 — Parts of a Horizontal Mill Saddle
12. TM #12 — Parts of a Horizontal Mill Table
13. TM #13 — Major Parts of the Turret Mill
14. TM #14 — Parts of the Milling Head
15. TM #15 — Parts of a Turret Mill Ram and Swivel
16. TM #16 — Parts of a Turret Mill Table
17. TM #17 — Parts of a Turret Mill Saddle and Knee
18. TM #18 — Parts of a Dividing Head

E. Assignment sheets

1. Assignment Sheet #1 — Complete Milling Machine Safety Test
2. Assignment Sheet #2 — Perform Calculations Necessary for Direct and Simple Indexing
3. Assignment Sheet #3 — Calculate Machine Speed and Feed Rates

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Clean and Lubricate a Horizontal Mill
2. Job Sheet #2 — Clean and Lubricate a Vertical Mill

H. Test

I. Answers to test

III. Unit references

A. Anderson, James, and Earl E. Tatro. *Shop Theory*, 5th ed. New York: McGraw-Hill Book Company, 1968.

SUGGESTED ACTIVITIES

B. *The Bridgeport CNC's.* Bridgeport, Connecticut: Bridgeport Machines, 1981.

C. *Bridgeport Series I Milling Machine: Manual No. M-105-E.* Bridgeport, Connecticut: Bridgeport Machines, March 1979.

D. Feirer, John L., and Earl E. Tatro. *Machine Tool Metalworking: Principles and Practice.* New York: McGraw-Hill Book Company, Inc., 1961.

E. *Hart Industrial Catalogue.* Hillside, Illinois: Wallace Press, 1977.

F. *Instruction and Repair Parts Manual for 203-205 Cintimill.* Publication No. C-450-1. Cincinnati, Ohio: Cincinnati Lathe and Tool Company, n.d.

G. Kibbe, R., et al. *Machine Tool Practices* New York: John Wiley Publishing Co., 1979.

H. Krar, Stephen F., and T. William Oswald, and J.E. St. Adams. *Technology of Machine Tools.* Toronto: McGraw-Hill of Canada, 1969.

I. *Marsuco Catalog #680.* Grand Rapids, Michigan: Jaqua-McKee, Inc., 1979.

J. *Milling Machine Work.* Albany, New York: Delmar Publishers, 1953.

K. *Parkson M1700 Series Milling Machines.* Bradford, England: Hart & Clough Ltd., 1980.

L. *Stephens Industrial Supply Catalogue.* Hillside, Illinois: Wallace Press, 1977.

INTRODUCTION TO MILLING MACHINES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Milling — Machining flat, angular, circular, and tapered surfaces with a revolving cutter

B. Knee and column — Parts of milling machine that support and move table up and down by elevating crank

C. Saddle — Holds table and moves in and out traversely on knee; mounted to knee

D. Table — Part of machine on which work or work-holding devices are mounted; moves longitudinally through saddle

E. Trip dogs — Movable metal stops that are part of tripping mechanism used to control power movement of table, saddle, or knee by tripping the power-feed mechanism

F. Dividing head — Mechanism used to divide the circumference of a workpiece into a given number of spaces for milling or drilling

G. Rotary table — Round machine table on which a workpiece is secured and moved in a circular path, rotating workpiece to desired angle in relation to cutter

(NOTE: Some rotary tables have a compound base to allow adjustment.)

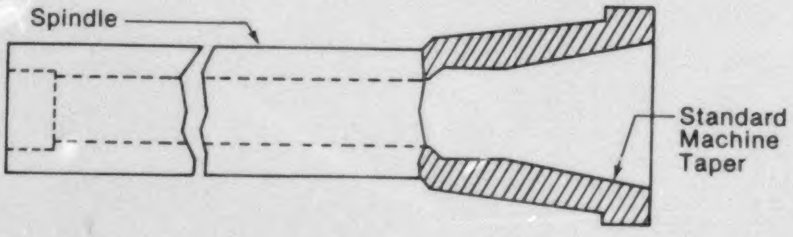
H. Sight gauge — Device that shows the required level of a lubricant for visual inspection

I. Standard machine taper — Method of designating milling machine spindles

(NOTE: The size of the taper will vary in diameter; however, the standard taper is 3 1/2 inches per foot. See Figure 1.)

EXAMPLE:

FIGURE 1

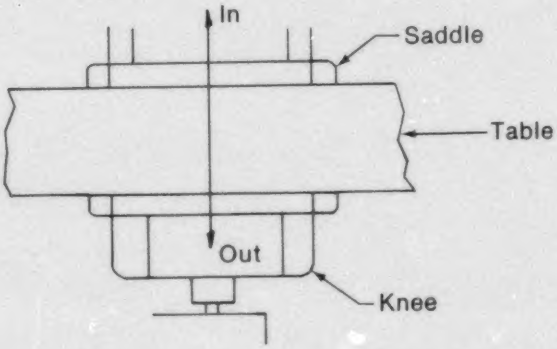


INFORMATION SHEET

J. Traversal — Lateral or crosswise movement of saddle (Figure 2)

EXAMPLE:

FIGURE 2

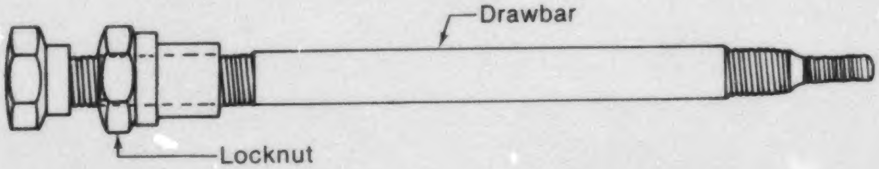

In
Saddle
Table
Out
Knee

K. Longitudinal — Movement of table right or left through saddle dovetails

L. Drawbar — Steel bolt that goes through spindle, screws into arbor or adapter, pulls arbor into spindle taper, and holds it in place with a locknut (Figure 3)

EXAMPLE:

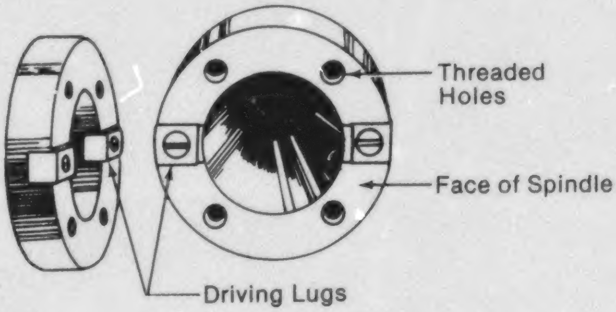
FIGURE 3


Drawbar
Locknut

M. Driving lugs — Metal lugs bolted to spindle to transmit power to arbor or adapter (Figure 4)

EXAMPLE:

FIGURE 4


Threaded Holes
Face of Spindle
Driving Lugs

INFORMATION SHEET

N. Backlash — Amount of lost motion (play) in moving parts when reversing direction of feed in a screw or gear

O. Override — Device or process that allows machine to operate outside the limits set by selectors or other machine parts

EXAMPLE: Although the table may be set at 2 1/2 inches per minute, when the rapid traverse lever is engaged, the table setting is overridden, and the table moves at 20 inches per minute; when the lever is disengaged, the table feed returns to the setting.

II. Types of milling machines (Transparencies #1-#7)

A. Horizontal mill

B. Turret mill

C. Vertical mill

D. Tracer or duplicating mill

E. Bed-type manufacturing mill

F. Precision jig bore

G. Computerized mill

III. Major parts of the horizontal knee-and-column mill (Transparency #8)

A. Overarm

B. Start/stop switches

C. Spindle

D. Overarm support

E. Table

F. Saddle

G. Knee

H. Elevating screw housing

I. Base

J. Knee motor drive

INFORMATION SHEET

- K. Spindle motor cover
- L. Spindle reversing lever
- M. High/neutral/low selector lever
- N. Column

IV. Uses of specific parts of the horizontal mill

A. Column (Transparency #9)

1. Base — Supports column, serves as reservoir for coolant, and provides base for elevating screw
2. Spindle motor cover — Allows access to spindle motor for maintenance
3. Spindle reversing lever — Sets direction of spindle rotation
4. Spindle speed indicating dial — Selects revolutions per minute (rpm) at which spindle turns
5. High/neutral/low selector lever — Permits speed mechanisms to be used in two speed ranges
6. Ways — Guide and support knee, saddle, and table
7. Overarm slide — Guides movement of ram-type overarm
8. Overarm lockbolts — Secure overarm to column
9. Spindle — Aligns and drives different kinds of arbors

B. Knee (Transparency #10)

1. Rapid traverse lever — Overrides setting of feed indicating dial, allowing table to move at a higher rate of feed
2. Graduated collars — Indicate amount of cross-feed movement or elevating movement in thousandths of an inch
3. Cross-feed handwheel — Provides for manual traverse travel of table and saddle
4. Elevating crank — Moves knee assembly up or down by means of elevating screw

INFORMATION SHEET

5. Feed indicating dial — Selects rate at which machine feeds in longitudinal, traversal, or vertical travel

6. Power elevating lever — Moves knee assembly up or down by power at rate of feed set by feed dial

7. Elevating screw housing — Provides support for knee; houses elevating screw mechanism

8. Knee drive motor — Provides power movement to knee for elevating, traversal, and longitudinal movements

9. Knee lock — Locks knee to column

C. Saddle (Transparency #11)

1. Table clamp screws — Lock table in position

2. Longitudinal-feed lever — Engages power feed for longitudinal travel of table

3. Saddle lock — Locks saddle to knee

4. Ways — Slide on knee; guide table by means of dovetails

D. Table (Transparency #12)

1. T-slots — Allow work-holding devices to be secured to table

2. Graduated collar — Indicates amount of table movement in thousandths of an inch

3. Longitudinal-feed handwheel — Moves table by hand

4. Positive end stops — Limit maximum movement of table

5. Trip dogs — Slide in slots on table, are adjusted to desired length of feed, and stop feed when contact is made with table engaging lever

V. Major parts of the turret mill (Transparency #13)

A. Motor

B. Milling head

C. High/neutral/low selector lever

D. Column

INFORMATION SHEET

E. Table

F. Base

G. Elevating screw housing

H. Knee

I. Saddle

J. Spindle

K. Speed indicator

L. Spindle power feed

M. Drawbar

N. Ram

VI. Specific parts of the turret mill and their correct uses

A. Milling head (Transparency #14)

1. Variable speed dial — Indicates speed of spindle in high or low range
2. High/neutral/low selector lever — Sets speed range of spindle
3. Quill feed handle — Feeds quill during manual movement
4. Quill stop — Moves with quill, trips feed control lever when depth is reached, and stops power quill movement
5. Quill lock — Locks quill
6. Micrometer adjusting nut — Adjusts quill movement to a precise depth; graduated in thousandths of an inch
7. Spindle — Houses cutter holder and transmits rotary motion to cutter
8. Quill — Houses spindle and bearing; moves in or out of mill head for drilling, boring, and other operations

INFORMATION SHEET

9. Feed control lever — Starts and stops quill
10. Quill feed direction selector — Selects direction of feed for quill (up or down)
11. Manual feed wheel — Feeds quill by hand
12. Quill feed selector — Sets rate of feed for quill
13. Power-feed transmission engagement crank — Engages or disengages power feed of quill
14. Spindle brake — Locks spindle to allow tightening or loosening of drawbar
15. Variable speed control — Increases or decreases spindle speed

B. Ram and swivel (Transparency #15)

1. Head swivel positioning screw — Moves head right or left
2. Head tilting shaft — Allows head to be swiveled in (toward column) or out (away from column)
3. Head tilting lockbolts — Lock position of head at set angle along ram axis
4. Ram locking screw — Secures ram in position
5. Ram positioning lever — Moves ram back and forth in swivel
6. Swivel locking screw — Secures swivel in position
7. Swivel — Allows ram and working head to be rotated to different positions
8. Head swivel locking screws — Secure head at set angle perpendicular to ram axis

C. Table (Transparency #16)

1. Graduated collar — Indicates amount of table movement in thousandths of an inch
2. Table handcranks — Move table longitudinally
3. Power-feed attachment — Indicates and selects rate of table feed for power movement

INFORMATION SHEET

4. Power-feed control lever — Engages power-feed mechanism
5. Table stops — Limit movement of table

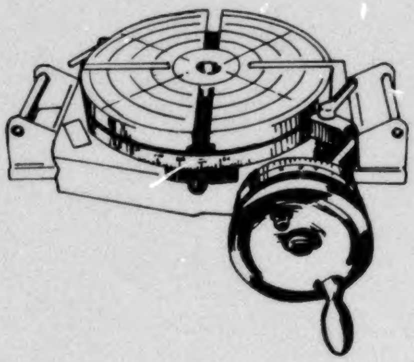
D. Saddle and knee (Transparency #17)

1. Table locks — Lock position of table in saddle
2. Saddle lock — Locks position of saddle on knee
3. Graduated collars — Indicate amount of cross-feed movement or elevating movement in thousandths of an inch
4. Elevating handcrank — Moves knee up and down
5. Cross-feed handcrank — Moves saddle in and out with micrometer accuracy
6. Knee lock — Locks position of knee to column

VII. Work-holding devices (Figures 5-14)

A. Rotary table

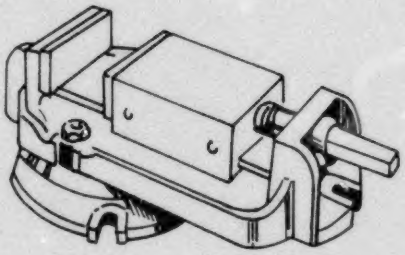
FIGURE 5



INFORMATION SHEET

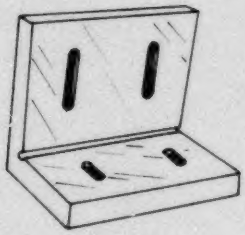
B. Vise with swivel base

FIGURE 6



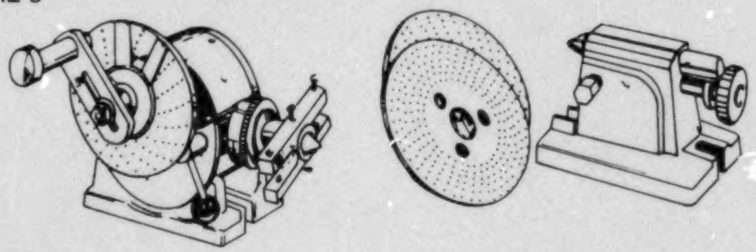
C. Angle plate

FIGURE 7



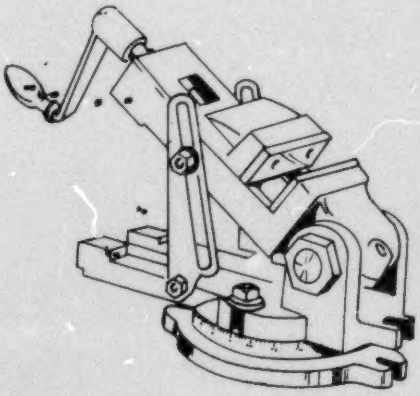
D. Indexing (dividing) head and attachments

FIGURE 8



E. Heavy-duty angle vise

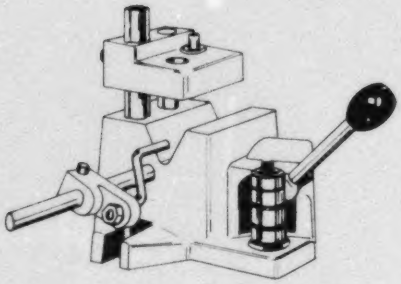
FIGURE 9



INFORMATION SHEET

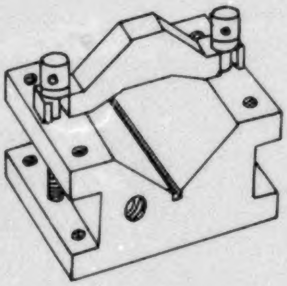
F. Fixture

FIGURE 10



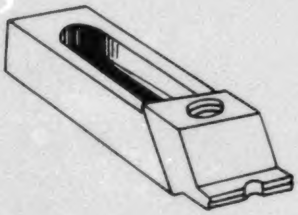
G. V-block and clamp

FIGURE 11



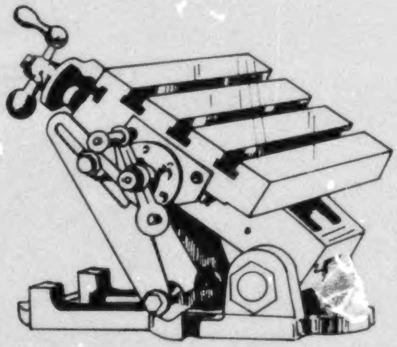
H. Hold-down clamp

FIGURE 12



I. Precision angle table (adjustable)

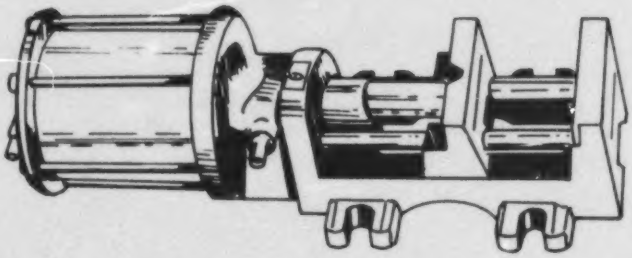
FIGURE 13



INFORMATION SHEET

J. Air vise

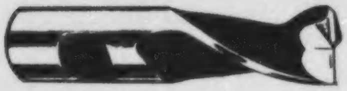
FIGURE 14



VIII. Cutting tools (Figures 15-40)

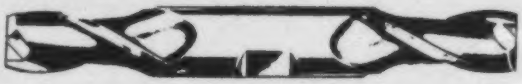
A. Two-flute helical end mill

FIGURE 15



Single End

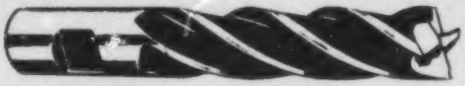
FIGURE 16



Double End

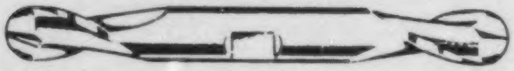
B. Four-flute end mill

FIGURE 17



C. Ball-nose end mill

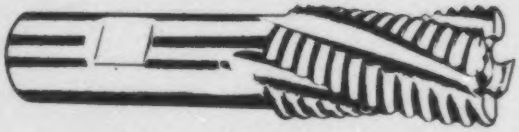
FIGURE 18



INFORMATION SHEET

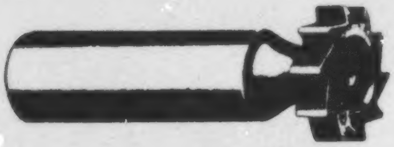
D. Roughing end mill

FIGURE 19



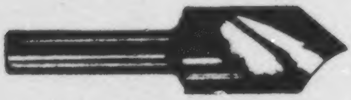
E. Woodruff keyseat cutter

FIGURE 20



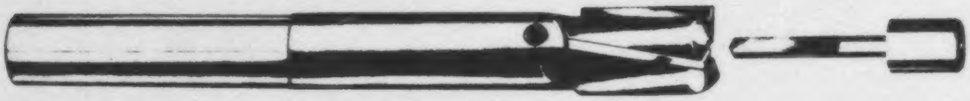
F. Countersink

FIGURE 21



G. Counterbore with pilot

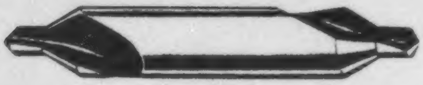
FIGURE 22



INFORMATION SHEET

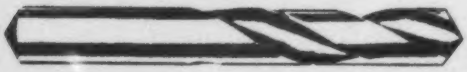
H. Combination drill and countersink (center drill)

FIGURE 23



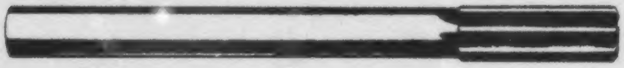
I. Straight-shank drill

FIGURE 24



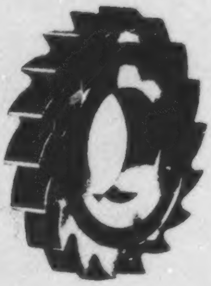
J. Reamer

FIGURE 25



K. Plain mill cutter

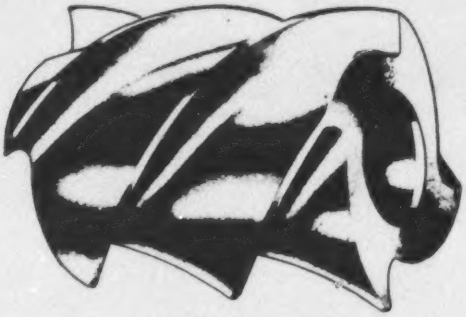
FIGURE 26



INFORMATION SHEET

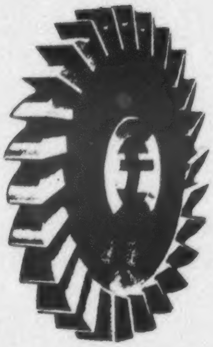
L. Helical mill cutter

FIGURE 27



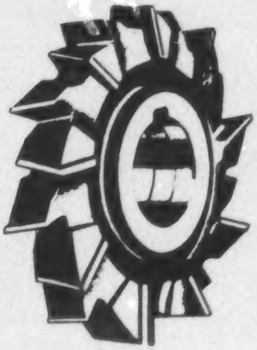
M. Side mill cutter

FIGURE 28



N. Staggered-tooth mill cutter

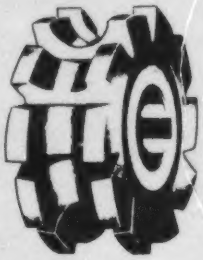
FIGURE 29



INFORMATION SHEET

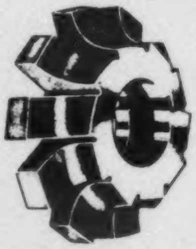
O. Concave mill cutter

FIGURE 30



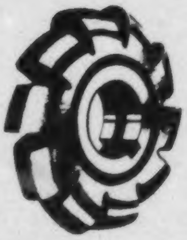
P. Corner-rounding mill cutter (radius cutter)

FIGURE 31



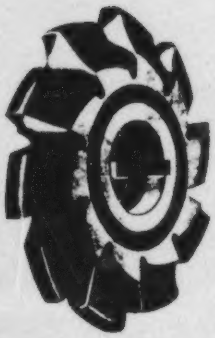
Q. Convex mill cutter

FIGURE 32



R. Involute gear cutter

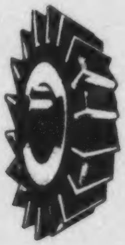
FIGURE 33



INFORMATION SHEET

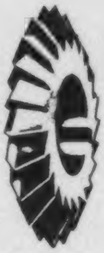
S. Single-angle mill cutter

FIGURE 34



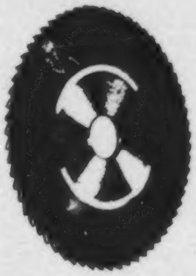
T. Double-angle mill cutter

FIGURE 35



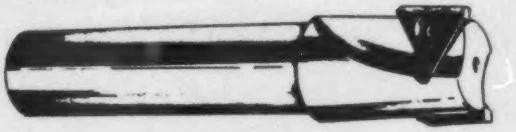
U. Plain metal-slitting saw

FIGURE 36



V. Insert-type end mill

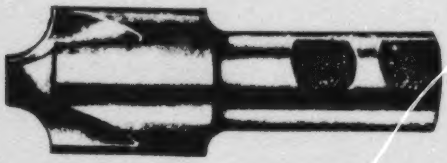
FIGURE 37



INFORMATION SHEET

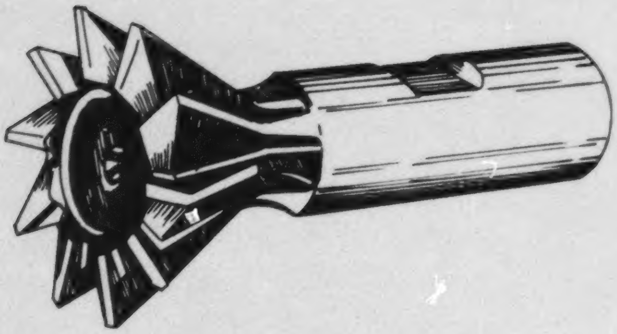
W. Corner-rounding end mill (radius-cutting end mill)

FIGURE 38



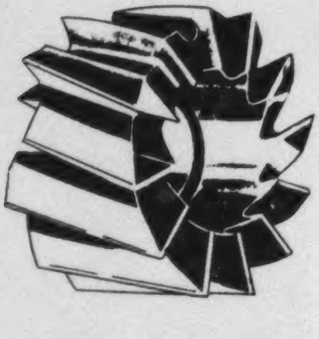
X. Dovetail-cutting end mill

FIGURE 39



Y. Shell mill cutter

FIGURE 40

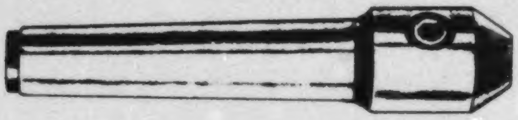


INFORMATION SHEET

IX. Toolholders for cutting tools (Figures 41-47)

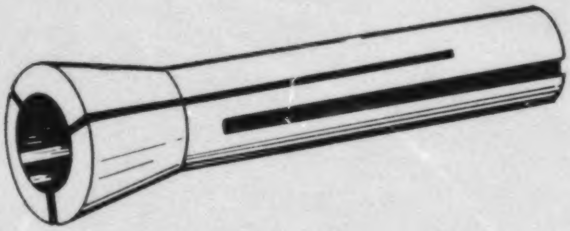
A. End mill holder

FIGURE 41



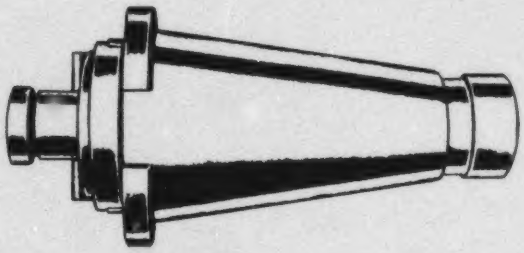
B. Collet

FIGURE 42



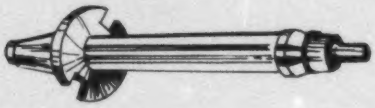
C. Shell mill arbor

FIGURE 43



D. Style A arbor

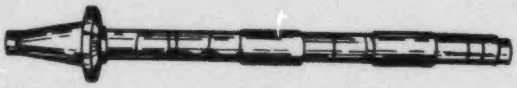
FIGURE 44



INFORMATION SHEET

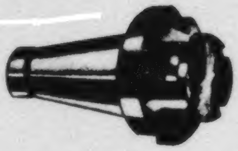
E. Style B arbor

FIGURE 45



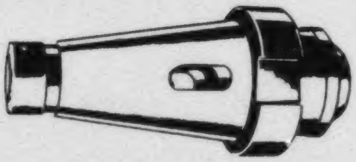
F. Style C arbor

FIGURE 46



G. Taper adapter

FIGURE 47



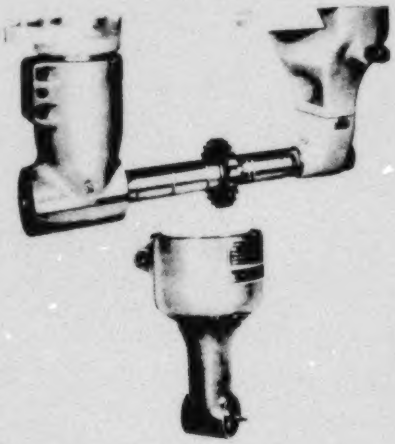
INFORMATION SHEET

X. Attachments and their uses

A. Horizontal attachment for vertical mill — Changes axis of vertical mill spindle so that arbors can be mounted to use cutters other than end mill cutters; also used to hold drills, reamers, and mill cutters parallel to table (Figure 48)

EXAMPLE:

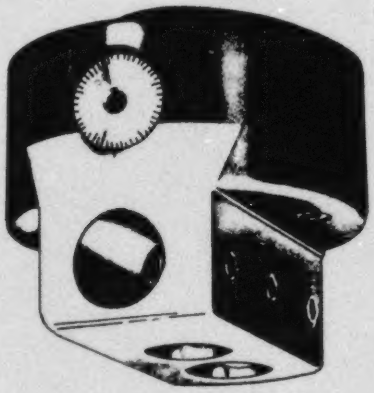
FIGURE 48



B. Boring head — Enlarges an existing hole to an exact size (Figure 49)

EXAMPLE:

FIGURE 49

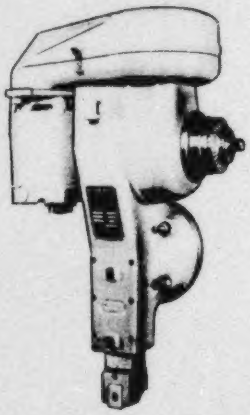


INFORMATION SHEET

C. Slotting head — Shapes internal or external surfaces (Figure 50)

EXAMPLE:

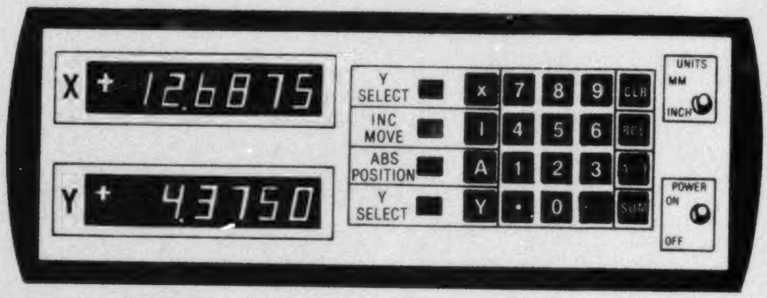
FIGURE 50



D. Digital readout — Indicates precise distance of axis movement, gives positive reading of precision movements, and eliminates need to consider backlash in lead screw (Figure 51)

EXAMPLE:

FIGURE 51

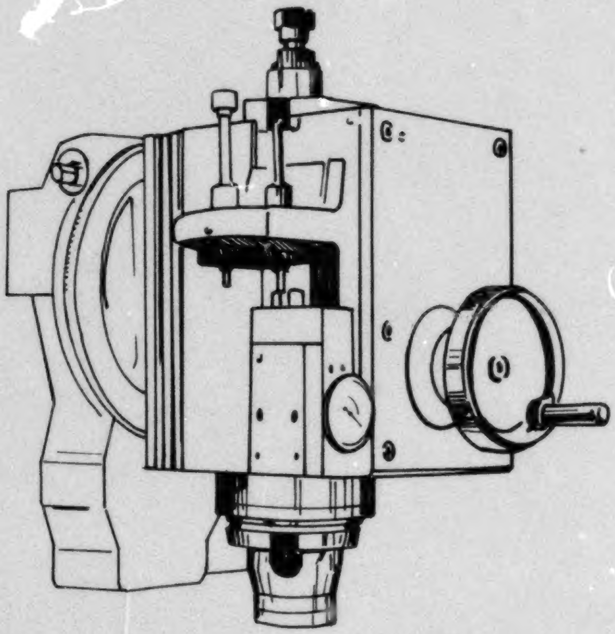

X
+ 12.6875
Y
+ 4.3750
Y SELECT
INC MOVE
ABS POSITION
Y SELECT
x
I
A
Y
7
8
9
4
5
6
1
2
3
•
0
CLR
SUM
UNITS
MM
INCH
POWER
ON
OFF

INFORMATION SHEET

E. Vertical head for horizontal mill — Converts spindle drive so that it is perpendicular to table (Figure 52)

EXAMPLE:

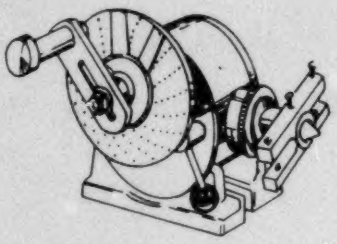
FIGURE 52



F. Dividing or indexing head — Allows very precise rotation of workpiece for repeated cutting operations such as required for gears, splines, or cams (Figure 53)

EXAMPLE:

FIGURE 53



(NOTE: Other special attachments that are not shown may be used when gear cutting and helical milling.)

INFORMATION SHEET

XI. Milling machine safety (Assignment Sheet #1)

A. Rags — Use when handling cutters to avoid injury to hands; however, do not use around revolving cutters

B. Setup — Make sure that setup holds workpiece rigidly and that workpiece is tightly clamped to prevent slippage under cutter force, which may result in damage to cutter or workpiece or in injury to personnel

C. Cutting tools — Make sure that cutting tools are always keyed to arbor or held securely in holder to prevent slippage

D. Feed — Adjust so that workpiece moves at proper feed to prevent damage to cutter and to produce desired finish

E. Cutter rotation — Adjust so that cutter rotates at proper surface feet per minute to prevent damage to cutter

F. Measurements or adjustments — To eliminate the possibility of an accident, stop cutter rotation before taking measurements or making adjustments

G. Conventional or up-milling — Feed work into cutter or against rotation of cutter when making heavy cuts

H. Changing parts — To avoid possible injury to hands or arms, move workpiece as far away from cutter as possible

I. Arbor nut and drawbar — Never attempt to tighten or loosen arbor nut or drawbar with machine power

J. Revolving cutter — Never reach over or touch revolving cutter with hands

K. Machine controls — Know location and use of all machine controls

(CAUTION. Never let another person operate controls for you.)

L. Running machine — Always stay within reach of stop switch while machine is running; never leave a running machine unattended

M. Travel levers — Always check machine travel levers before using machine

N. Positioning workpiece — Always use handcranks when positioning workpiece near cutter; never use power to set up

O. Standing by machine — Never lean on machine

INFORMATION SHEET

P. Warning tags or signs — Never use a machine that has a sign or warning tag indicating a dangerous condition or indicating that machine needs repair

Q. Chips — Never handle chips with bare hands because they can cut or burn

R. Compressed air — Take extreme caution to avoid forcing chips between work surfaces and to prevent injury from flying chips

S. Work area — To prevent the possibility of slipping or stumbling, keep area around machine clean and free of oil, chips, and other obstructions

T. Heavy objects — Use a hoist or ask for help when lifting

U. Guards — Never operate a machine with guards removed

V. Clothing — Wear close-fitting clothing, with shirt tucked in and sleeves buttoned or rolled above elbows

W. Safety glasses with side shields — Wear at all times

XII. Parts of the indexing or dividing head (Transparency #18)

A. Spindle nose

B. Direct-indexing plunger and pin

C. Direct-indexing holes

D. Sector arms

E. Indexing crank plunger pin

F. Indexing plate

G. Indexing crank

H. Sector arm lockscrew

I. Indexing plate stop

J. Spindle lock

XIII. Descriptions or functions of parts of the indexing or dividing head

A. Spindle nose — Has a machine taper that centers work-holding devices

INFORMATION SHEET

B. Spindle lock — Mechanical lock that prevents spindle from moving

C. Direct-indexing plunger and pin — Locate and lock in correct indexing hole when direct indexing

D. Direct-indexing holes — Located on spindle nose; provide for rapid indexing of parts that have divisions in multiples of 15 degrees

E. Sector arms — Two movable arms that travel set number of holes in hole plate each time indexing crank is turned

F. Indexing crank plunger pin — Locates exact movement of indexing crank

G. Indexing plate — Disc with circular hole patterns used to set workpiece rotation to a specific partial turn

(NOTE: Depending on the manufacturer, the indexing plate may consist of one reversible disc or three separate discs.)

H. Indexing crank — Turns gearing mechanism of dividing head to rotate workpiece

I. Sector arm lockscrew — Allows sector arms to be set for a particular number of holes and then locked

J. Indexing plate stop — Locks indexing plate for simple indexing; must be disengaged for direct indexing

XIV. Operations performed on dividing or indexing head

A. Cutting splines

B. Cutting gears

C. Cutting helixes

D. Cutting cams

E. Machining straight-tooth clutches

F. Machining flats at designated angles

G. Drilling holes at designated angles

H. Ruling or graduating parts

INFORMATION SHEET

XV. Calculating direct and simple indexing (Assignment Sheet #2)

A. Direct indexing

(NOTE: Direct indexing is done with a twenty-four-hole plate and can be used only if the number of repeated operations to be performed on the part will divide into twenty-four evenly.)

1. Determine number of workpiece divisions

EXAMPLES: Hexagon requires eight; twenty-four-tooth gear requires twenty-four.

2. Divide 24 by the required number of divisions to determine number of holes to move

EXAMPLE: Indexing for a hexagon (six sides)

$$\text{Indexing} = \frac{24}{\text{Number of Divisions (N)}}$$

$$= \frac{24}{6}$$

= 4 holes (To cut the hexagon, move the plate four holes after each cut.)

B. Simple indexing

(NOTE: Indexing heads use different ratios for the number of indexing crank turns to spindle turns. One of the most common ratios is 40:1, and that is the ratio discussed here.)

1. Divide 40 by the number of workpiece divisions, using the formula

$$\text{Turns of Crank (T)} = \frac{40}{\text{Number of Divisions (N)}}$$

(NOTE: The answer will be a whole number, a mixed number, or a fraction. See the examples below.)

EXAMPLES: Number of turns for an octagon (eight sides)

$$T = \frac{40}{N}$$

$$= \frac{40}{8}$$

= 5 turns

INFORMATION SHEET

Number of turns for a hexagon (six sides)

$$\begin{aligned} T &= \frac{40}{N} \\ &= \frac{40}{6} \\ &= 6\frac{4}{6} = 6\frac{2}{3}\text{ Turns} \end{aligned}$$

Number of turns for an eighty-tooth gear

$$\begin{aligned} T &= \frac{40}{N} \\ &= \frac{40}{80} \\ &= \frac{1}{2}\text{ turn} \end{aligned}$$

2. Determine number of holes in a partial turn

    a. Examine hole pattern in indexing plate

    EXAMPLES: Three indexing plates

Plate 1	15-16-17-18-19-20
Plate 2	21-23-27-29-31-33
Plate 3	37-39-41-43-47-49

    Reversible indexing plate

Side 1	24-25-28-30-34-37-38-39-41-42-43
Side 2	46-47-49-51-53-54-57-58-59-62-66

b. Find the smallest number that can be divided by the denominator of the partial turn fraction

EXAMPLES: $\frac{2}{3}$ turn

Three-plate set: 15, 18, 21, 27, 33, and 39 are divisible by 3; 15 is the smallest

Reversible indexing plate: 24, 30, 39, 42, 51, 54, 57, and 66 are divisible by 3; 24 is the smallest

c. Divide the smallest divisible hole pattern by the denominator to determine the number of holes in that fraction of a turn

EXAMPLES: $\frac{2}{3}$ turn

Three-plate set: $\frac{15}{3}$ = 5holes

Reversible indexing plate: $\frac{24}{3}$ = 8 holes

d. Multiply the number of holes in the fractional part by the numerator

(NOTE: Multiplying the number of holes in a fractional part by the numerator will give you the total number of holes in the partial turn.)

EXAMPLES: $\frac{2}{3}$ turn

Three-plate set: 5 x 2 = 10 holes; thus, 2/3 of a turn is 10 holes in 15-hole pattern

Reversible indexing plate: 8 x 2 = 16 holes; thus, 2/3 of a turn is 16 holes in the 24-hole pattern

INFORMATION SHEET

XVI. Reasons for using cutting fluids

A. To keep workpiece and tool cool

B. To reduce friction by lubrication

C. To help prevent chips from welding to cutter

D. To wash chips away from workpiece and cutter

XVII. Basic groups of cutting fluids

A. Cutting oils

EXAMPLES: Light-duty (Code #1) — Mineral oil, fatty oil, mineral oil/fatty oil mixture
Medium-duty (Code #2) — Sulfurized mineral oil, chlorinated mineral oil, sulfo-chlorinated oil
Heavy-duty (Code #3) — Mineral oil or sulfurized mineral oil plus sulfur, chlorine, or phosphorus compound

B. Emulsifiable oils

EXAMPLES: Light-duty (Code #4) — Soluble oil
Heavy-duty (Code #5) — Chlorinated soluble oil, sulfurized soluble oil, sulfo-chlorinated fatty soluble oil

C. Chemical and synthetic emulsions

EXAMPLES: Light-duty (Code #6) — Solutions or synthetic emulsions
Heavy-duty (Code #7) — Solutions or synthetic emulsions

D. Special cutting fluids

EXAMPLES: Light-duty (Code #8) — #80 honing oil, #81 amine nitrite and sodium nitrite solution, #87 cutting fluid for copper, #88 cutting fluid for magnesium
Heavy-duty (Code #9) — #90 honing oil

XVIII. Coolant application methods and descriptions

A. Flood cooling — Coolant under low pressure from one or more nozzles floods tool and workpiece; most common method of applying fluids

B. Mist system — Jet (10 to 80 psi) applies to cutter and workpiece mist of soluble or synthetic fluid mixed with air

INFORMATION SHEET

C. Paste or solid application — Coolant is applied to tool and workpiece manually by brush or oil can

D. Cold air — Pressurized cold air is directed over tool and workpiece

XIX. Advantages and disadvantages of methods for applying coolant

METHOD	ADVANTAGES	DISADVANTAGES
Flood cooling	Excellent lubrication and cooling Good chip removal	Expensive to use Messy Costly to install Obscures visibility of cut
Mist system	Good lubrication Good visibility of cut Excellent coolant distribution Easy to install	Limited cooling power Must be used in a well-ventilated area Subject to clogging Requires air source and filter system
Paste or solid application	Excellent for hand operations No additional equipment required Inexpensive	Dangerous when using power equipment Poor cooling power Poor chip control
Cold air	Good visibility of cut Easy to install Good chip control	No lubrication Expensive

XX. Possible causes of cutter failure and finish problems

A. Chatter

(NOTE: Chatter is both a problem and a condition that can lead to other problems.)

1. Workpiece not held rigidly
2. Workpiece not properly supported
3. Dull cutter
4. Excessive feed
5. Excessive revolutions per minute (rpm)

INFORMATION SHEET

6. Cutter not properly positioned
7. Cutter slipping

B. Cutter dulling rapidly

1. Excessive revolutions per minute (rpm)
2. Inadequate coolant at cut

   (NOTE: The coolant flow may be too slow, or the coolant may not be directed at the cut.)

3. Incorrect coolant
4. Chatter
5. Incorrect feed (high or low)
6. Too many teeth or flutes in cutter
7. Cutter ground improperly
8. Incorrect cutter

   (NOTE: The cutter may not be of the proper tool geometry for the operation and material being cut, or it may not be made of the proper material. Check the manufacturer's recommended applications.)

C. Cutting edge overheating

1. Excessive revolutions per minute (rpm)
2. Inadequate coolant at cut
3. Incorrect coolant
4. Incorrect cutter
5. Dull cutter
6. Cutter ground improperly
7. Cut too deep

INFORMATION SHEET

D. Cutting edge clogging

(NOTE: Chips can actually weld to the cutter, due to excessive heat and chip buildup.)

1. Too many teeth or flutes in cutter
2. Excessive revolutions per minute (rpm)
3. Excessive feed
4. Incorrect cutter
5. Inadequate coolant at cut
6. Incorrect coolant
7. Coolant flow direction wrong

E. Workpiece material hardening

1. Excessive revolutions per minute (rpm)
2. Excessive feed
3. Inadequate coolant at cut
4. Incorrect coolant
5. Dull cutter

F. Cutting edge chipping

1. Low revolutions per minute (rpm)
2. Chatter
3. Excessive feed
4. Not enough cutting edges
5. Cut too deep
6. Cutter ground improperly

INFORMATION SHEET

7. Loose gibs or play in table

   (NOTE: It is sometimes possible to overcome the problem of loose gibs or table play by tightening the gibs or by using conventional milling against the table screw.)

8. Chips being recut

9. Cutter slipping

10. Bent arbor

11. Outboard arbor bushing loose

G. Cutter breaking

   1. Excessive feed
   2. Cut too deep
   3. Workpiece not held rigidly
   4. Incorrect machine operation
   5. Dull cutter
   6. Loose gibs or play in table
   7. Cutter slipping

H. Excessive cratering of carbide

   1. Incorrect cutter
   2. Excessive revolutions per minute (rpm)
   3. Excessive feed
   4. Cutter ground improperly

XXI. Calculating machine speed and feed rates (Assignment Sheet #3)

A. Cutting speed (CS)

   1. Determine operation to be performed
   2. Determine material to be cut

INFORMATION SHEET

3. Determine type of cutting tool material to be used

4. Determine depth of cut

5. Refer to appropriate cutting speed table for operation, materials, and depth of cut

   (NOTE: Refer to the charts following Assignment Sheet #3.)

   EXAMPLE: Determine the cutting speed necessary to end mill a 1050 carbon bar to a depth of 0.200 of an inch using a high-speed steel cutter.

   CS = 75 sfpm

B. Spindle speed (rpm)

1. Determine cutting speed in surface feet per minute (sfpm) from tables

2. Convert cutting speed to spindle speed by using the following formula

$$\text{rpm} = \frac{4 \times \text{CS}}{\text{Diameter of Cutter in Inches}}$$

   (NOTE: The *4* is a constant.)

   EXAMPLE: Determine the spindle speed necessary to end mill a 1050 carbon bar to a depth of 0.200 of an inch using a $\frac{1}{2}$-inch diameter high-speed steel cutter.

$$\text{rpm} = \frac{4 \times \text{CS}}{\text{Diameter of Cutter in Inches}}$$

$$= \frac{4 \times 75}{0.5}$$

$$= \frac{300}{0.5}$$

$$= 600$$

C. Feed (ipm)

1. Determine rpm

2. Determine feed rate per tooth (Ft) by referring to required table

   (NOTE: Refer to tables following Assignment Sheet #3.)

INFORMATION SHEET

3. Determine number of teeth (T) on cutter

4. Convert feed rate per tooth to inches per minute (ipm) feed by using the following formula

Feed = Feed Rate per Tooth × Number of Teeth × Spindle Speed

EXAMPLE: Determine the feed necessary to end mill a 1050 carbon bar to a depth of 0.200 of an inch using a 1/2-inch diameter high-speed steel end mill with four flutes.

Feed = Feed Rate per Tooth × Number of Teeth × Spindle Speed

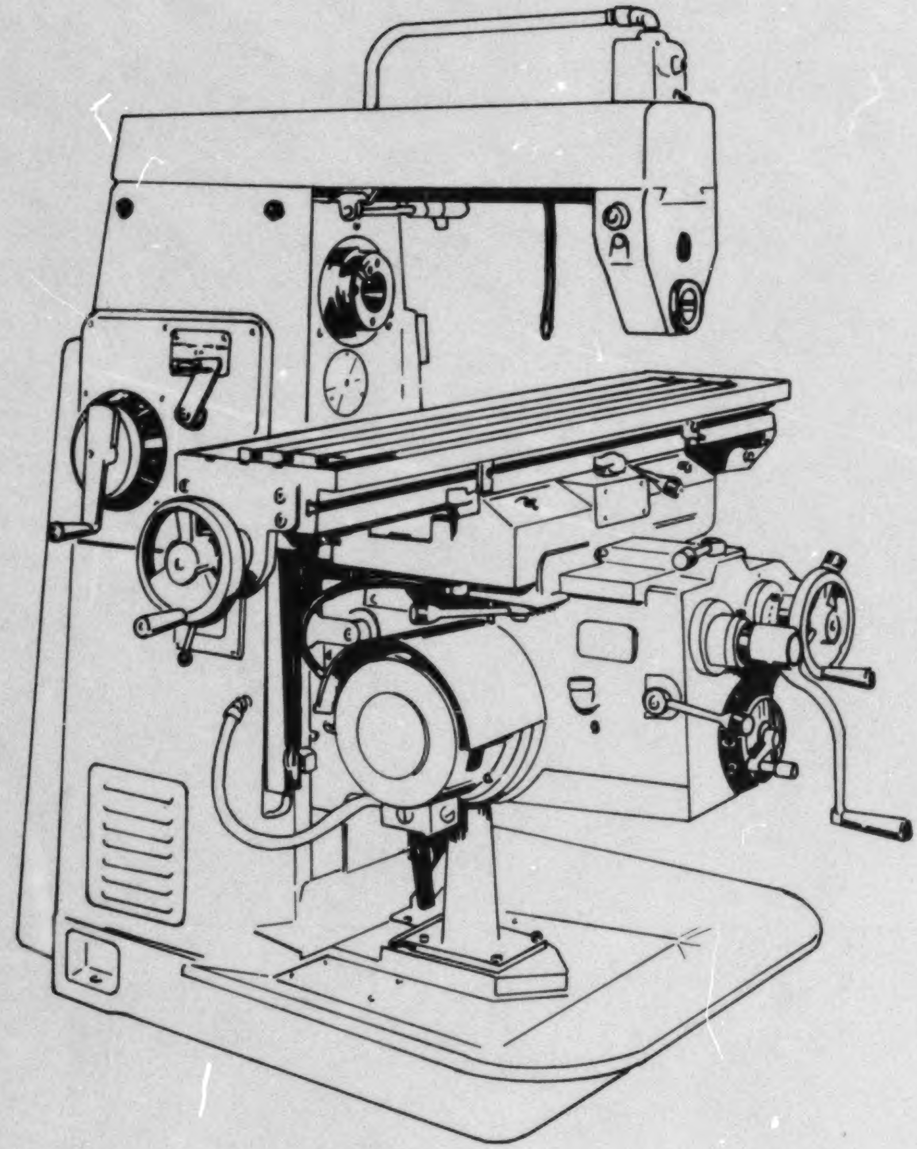
= Ft × T × rpm

= 0.001 × 4 × 600

= 2.4 ipm (If the table feeds at 2.4 ipm, each tooth on the cutter will remove 0.001 of an inch of material.)

(NOTE: The recommended speed and feed rates listed in the tables were obtained from experimentation using new machines, sharp cutters, and rigid setups. You may need to modify the calculations for your equipment. Overspeed [running cutter at too high rpm] and underfeed [moving the work too slowly] are the most common mistakes made in milling.)

Horizontal Mill



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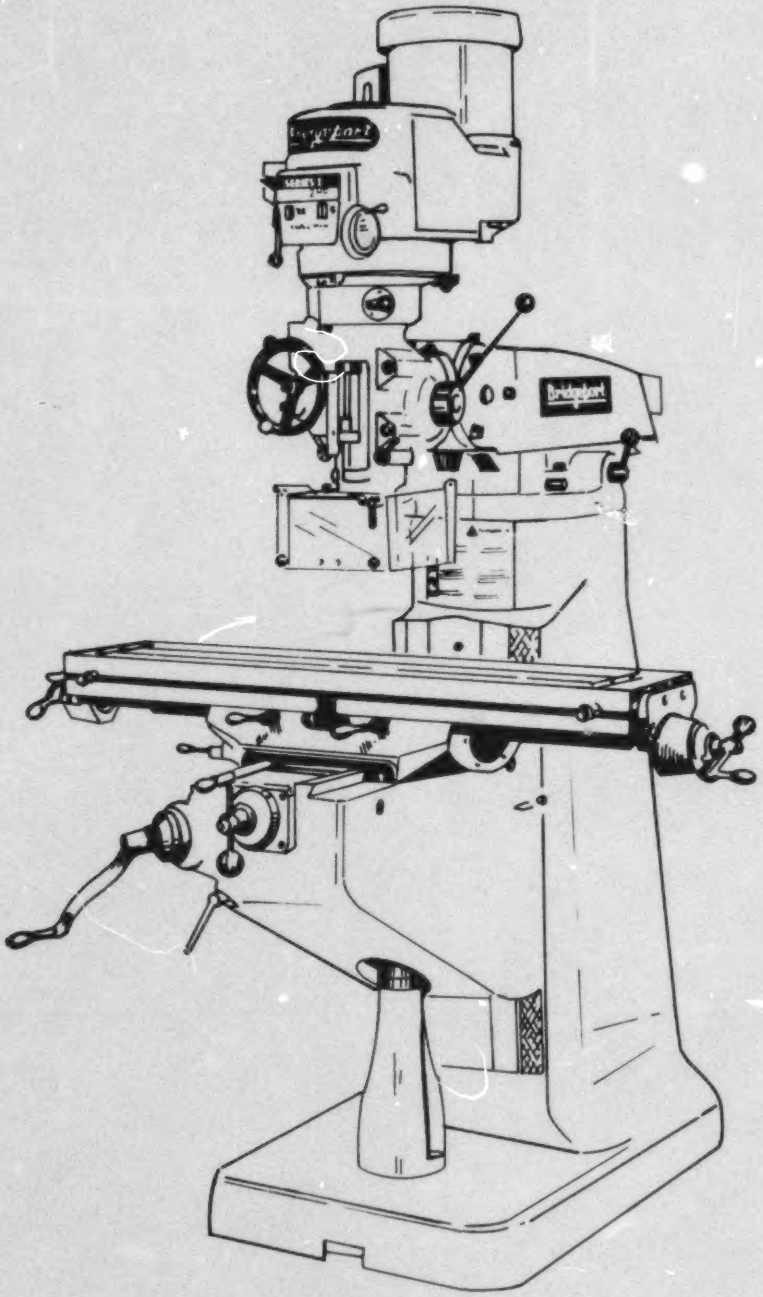
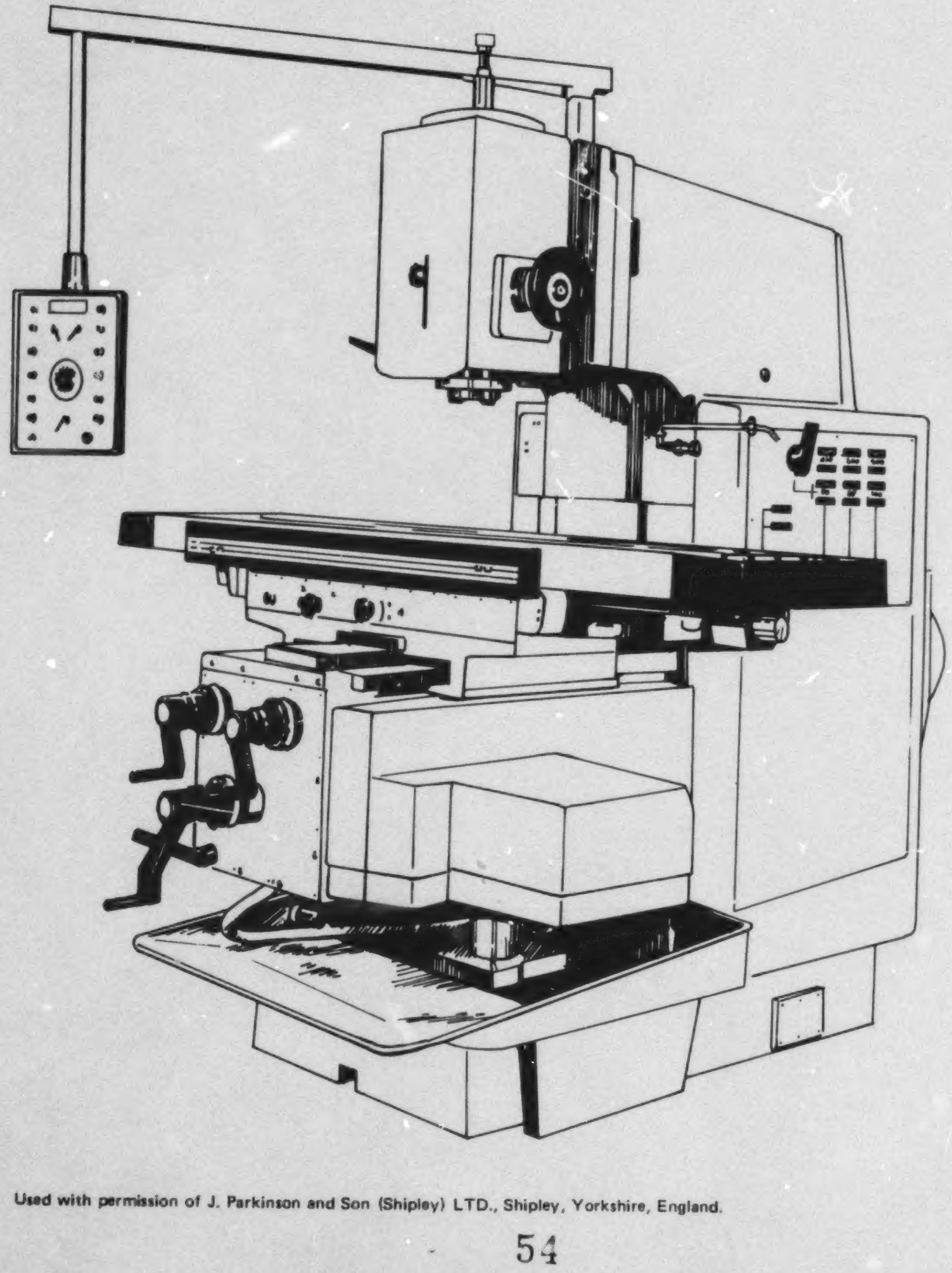
Turret Mill


Bridgeport
SERIES I
Bridgeport

Adapted with permission of Bridgeport Machines.

Vertical Mill



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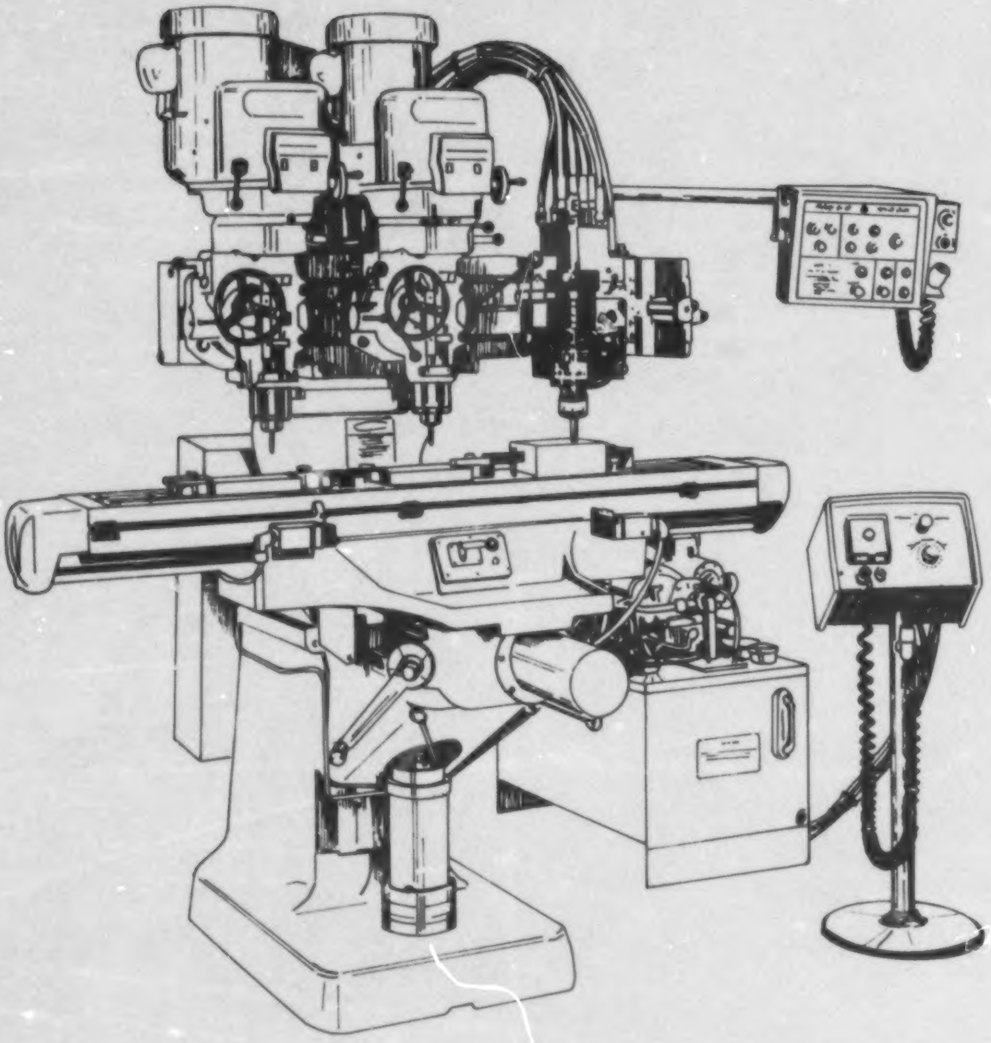
Tracer or Duplicating Mill



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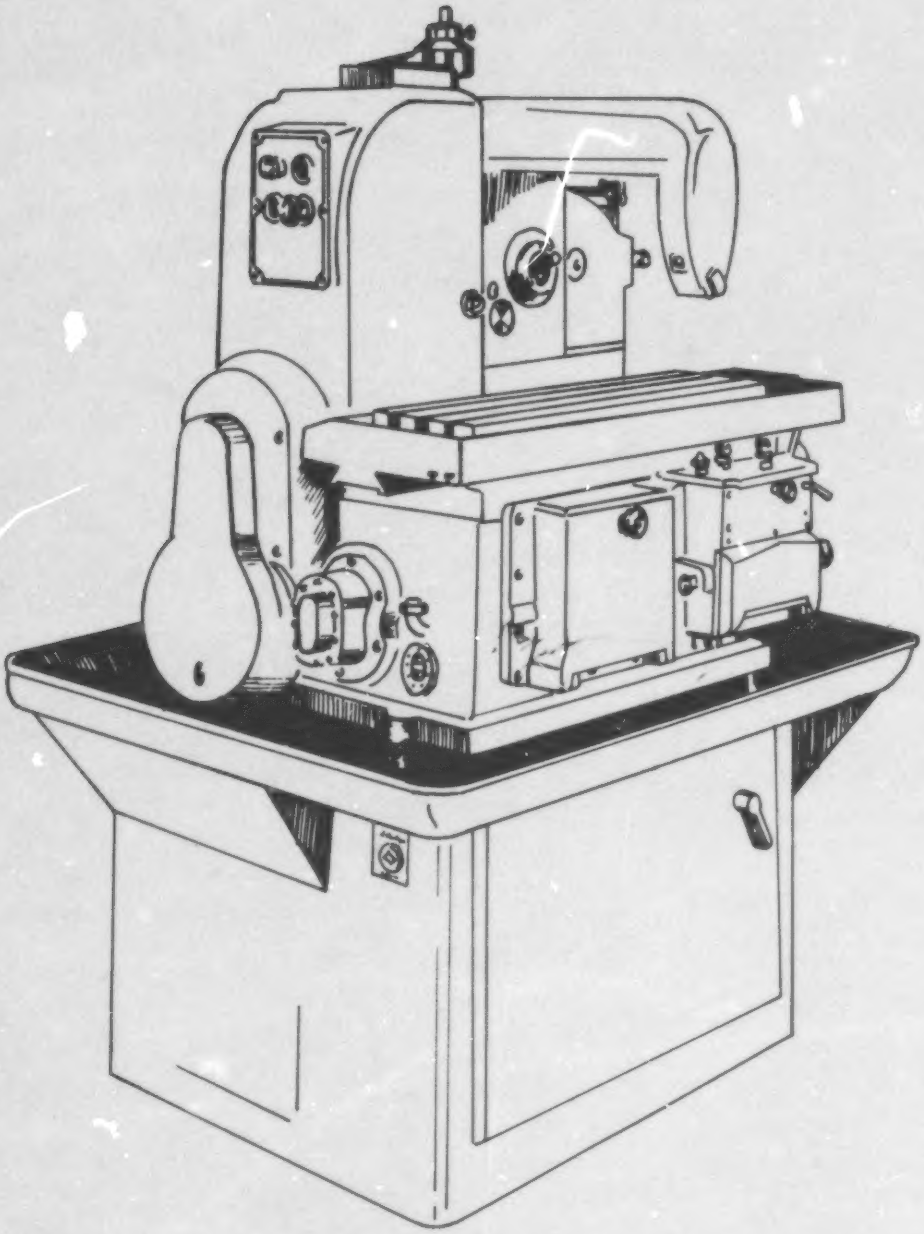
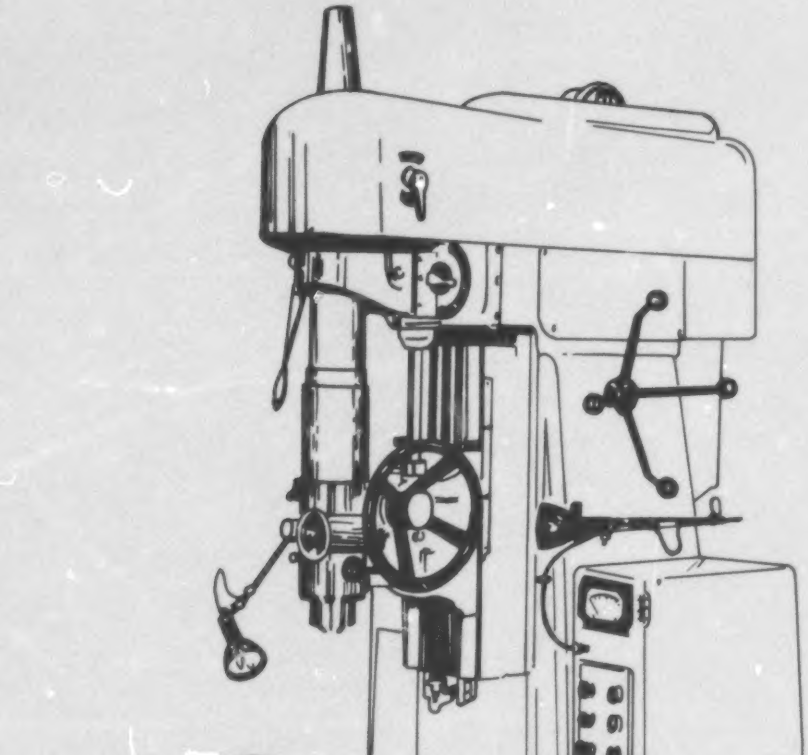
Bed-Type Manufacturing Mill



Precision Jig Borer



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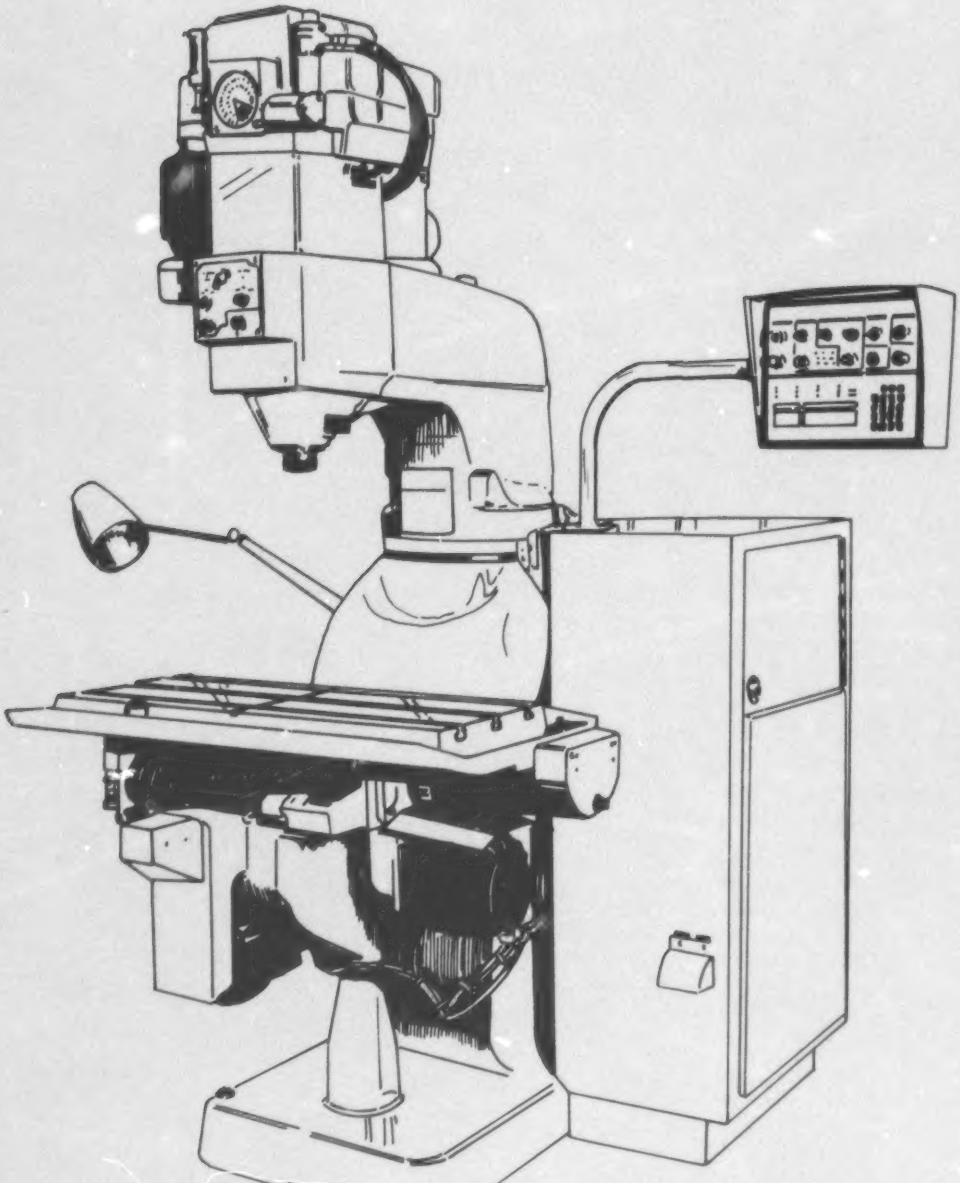
Computerized Mill



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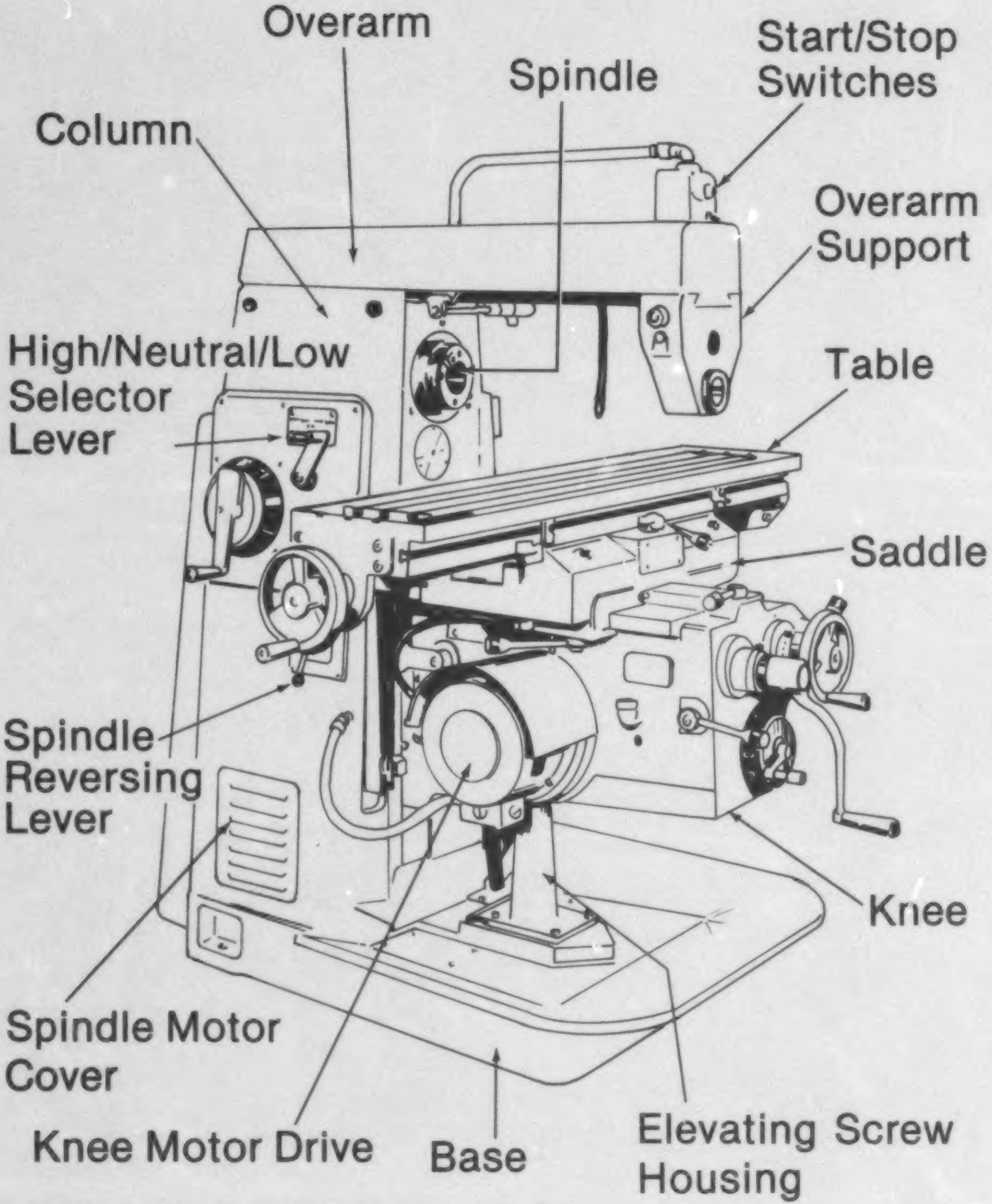
Major Parts of the Horizontal Mill


Overarm
Spindle
Start/Stop Switches
Column
Overarm Support
High/Neutral/Low Selector Lever
Table
Saddle
Spindle Reversing Lever
Knee
Spindle Motor Cover
Knee Motor Drive
Base
Elevating Screw Housing

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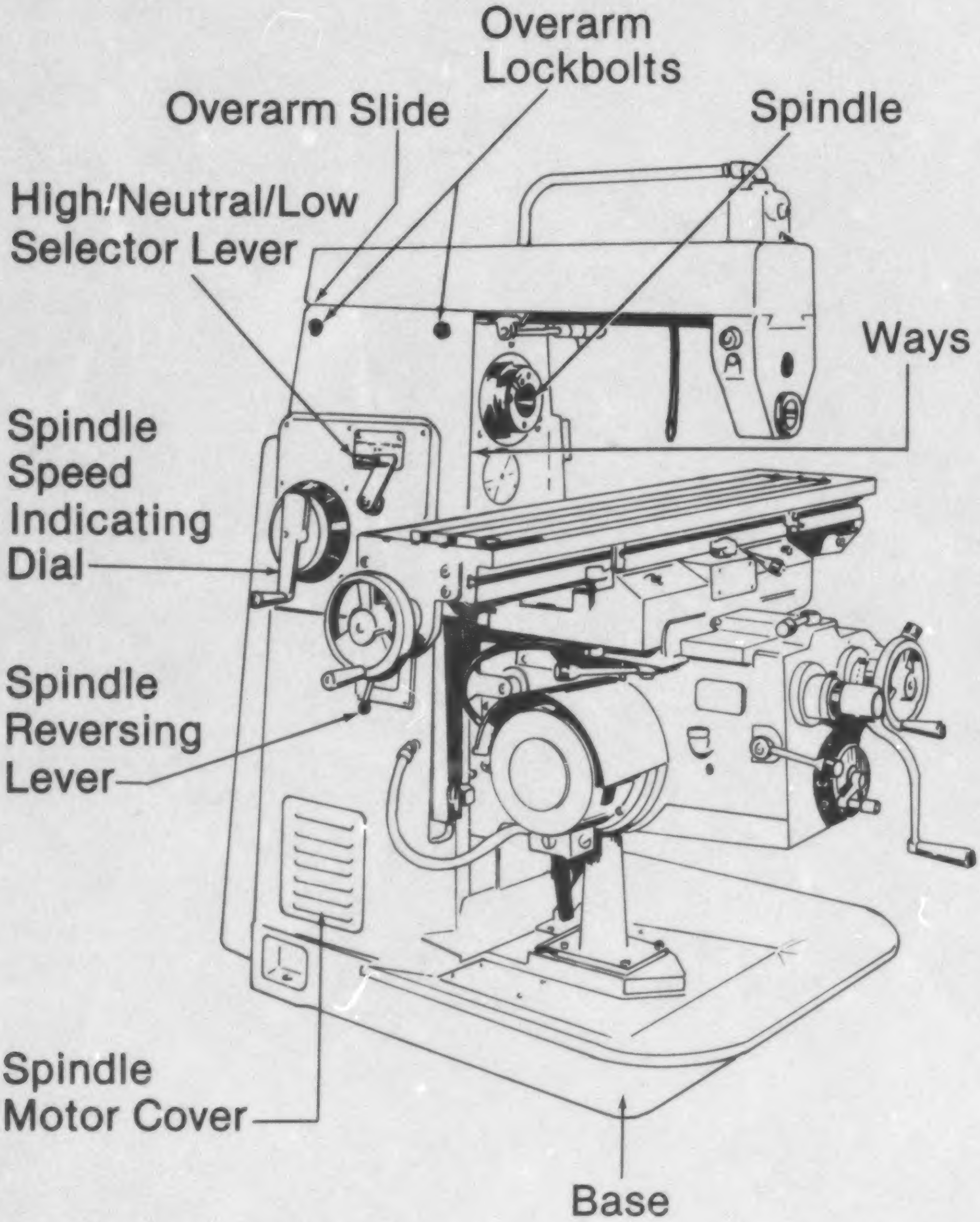
Parts of a Horizontal Mill Column


Overarm Lockbolts
Overarm Slide
Spindle
High/Neutral/Low Selector Lever
Ways
Spindle Speed Indicating Dial
Spindle Reversing Lever
Spindle Motor Cover
Base

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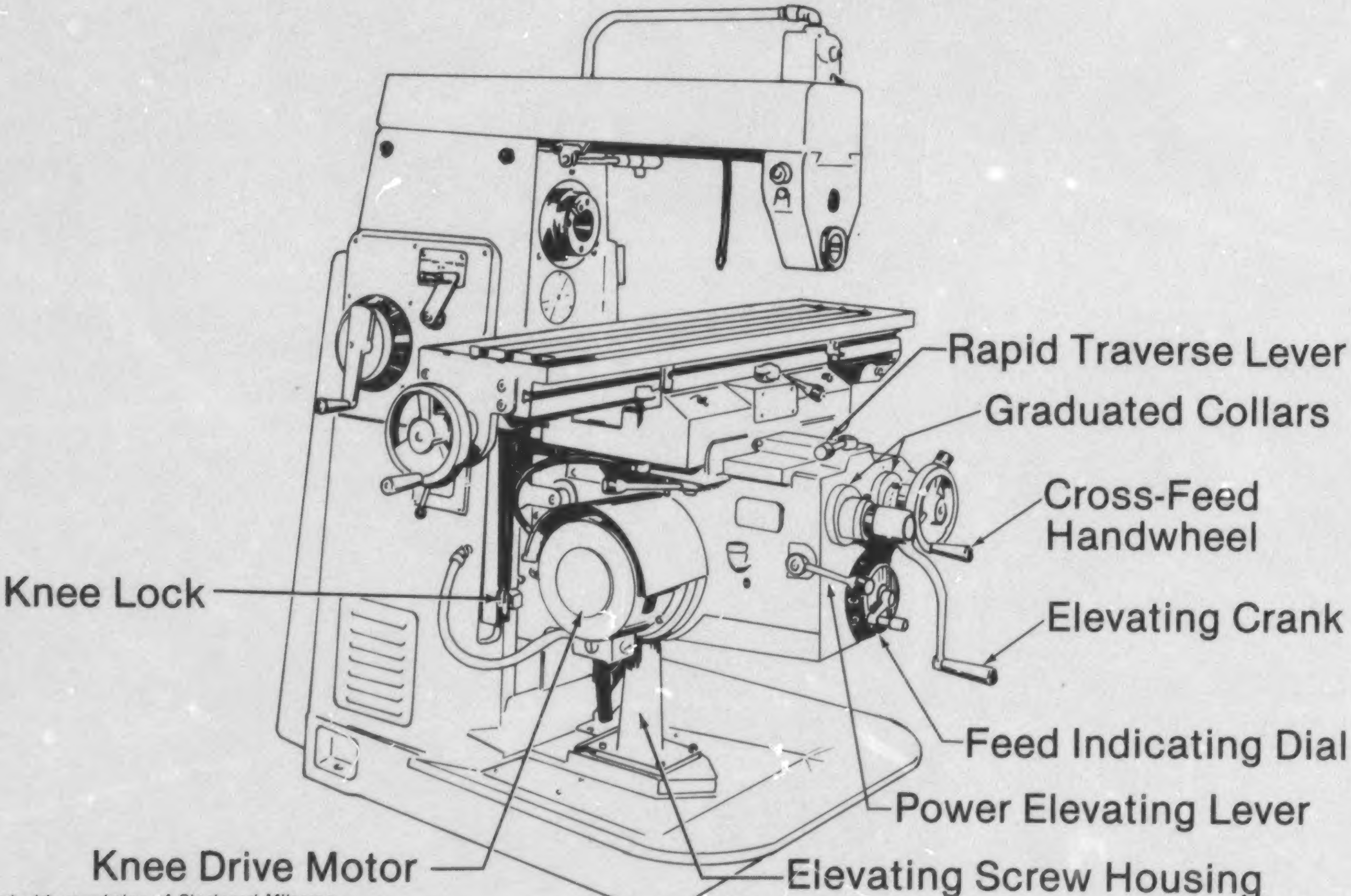
Parts of a Horizontal Mill Knee


Rapid Traverse Lever
Graduated Collars
Cross-Feed Handwheel
Knee Lock
Elevating Crank
Feed Indicating Dial
Power Elevating Lever
Knee Drive Motor
Elevating Screw Housing

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Parts of a Horizontal Mill Saddle

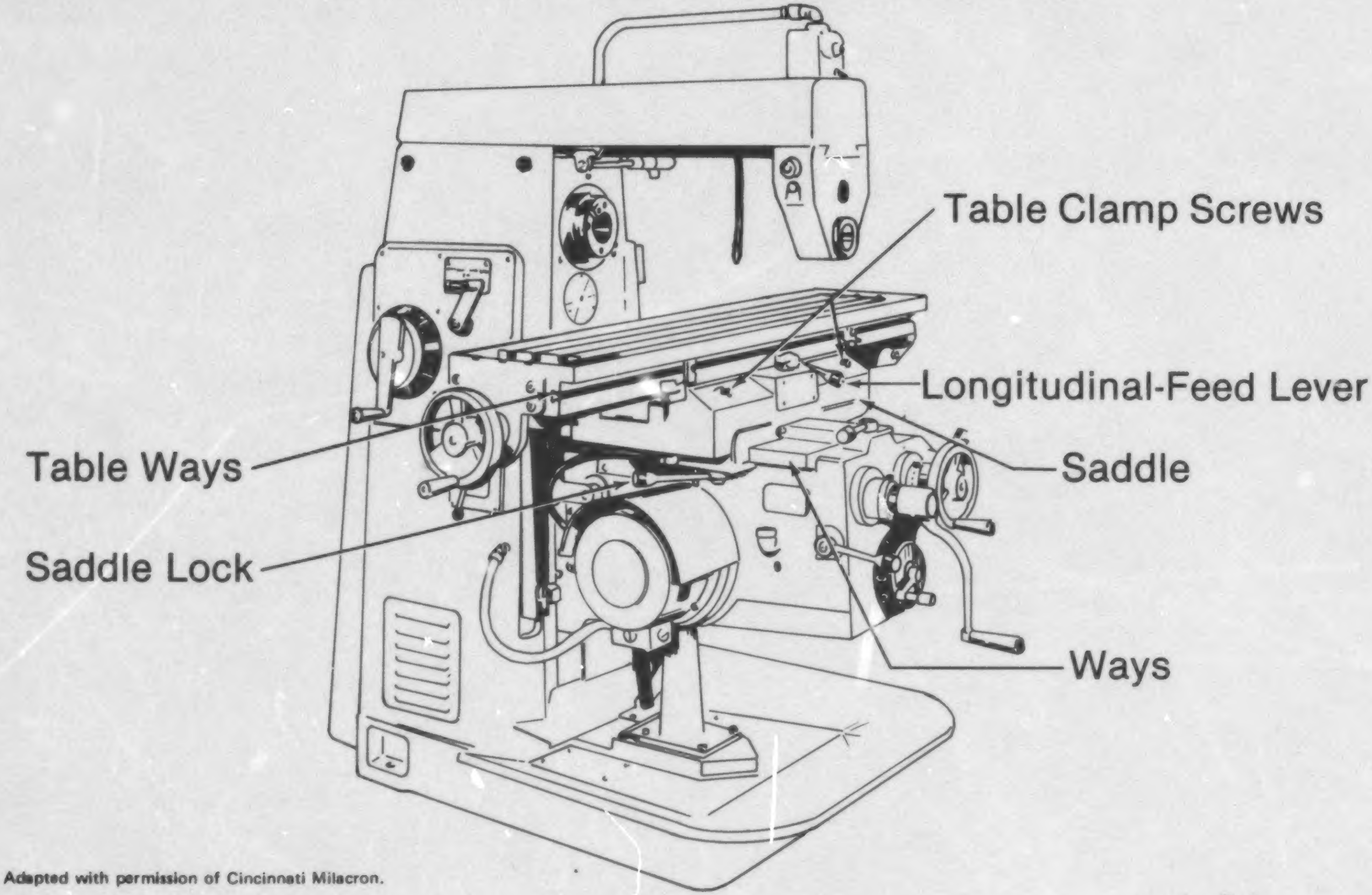
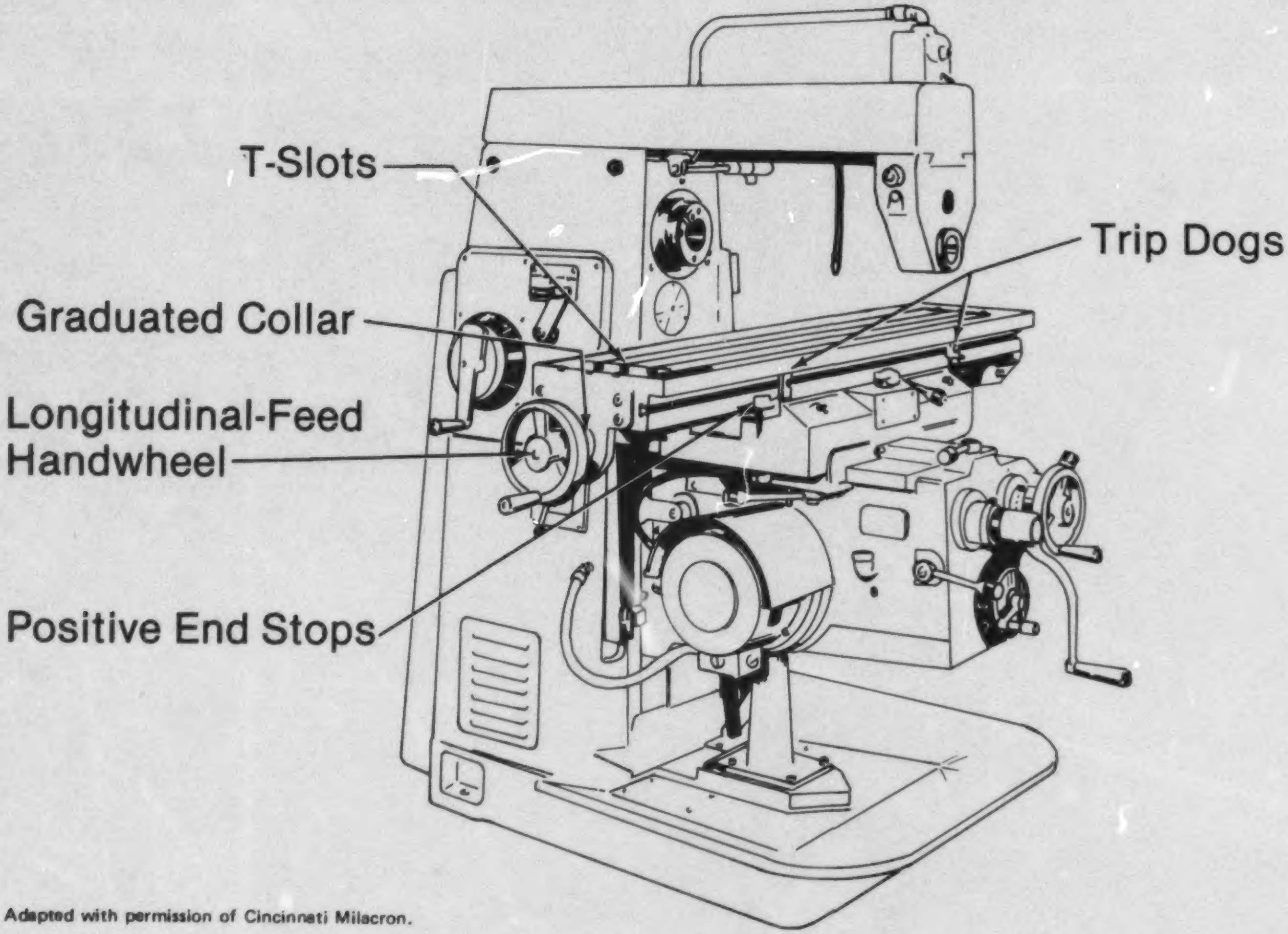


Table Clamp Screws
Longitudinal-Feed Lever
Table Ways
Saddle
Saddle Lock
Ways

Adapted with permission of Cincinnati Milacron.

Parts of a Horizontal Mill Table


T-Slots
Trip Dogs
Graduated Collar
Longitudinal-Feed Handwheel
Positive End Stops

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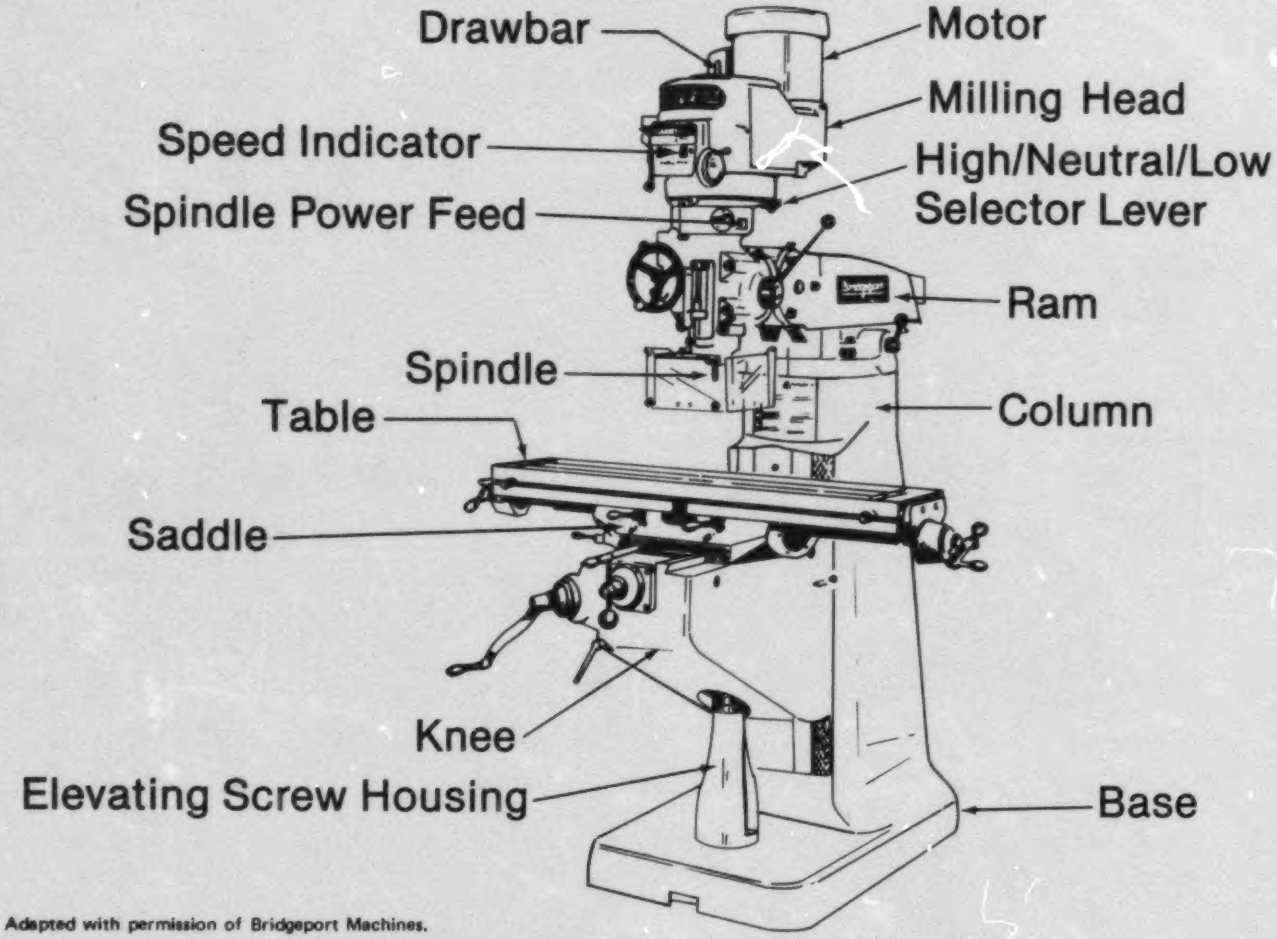
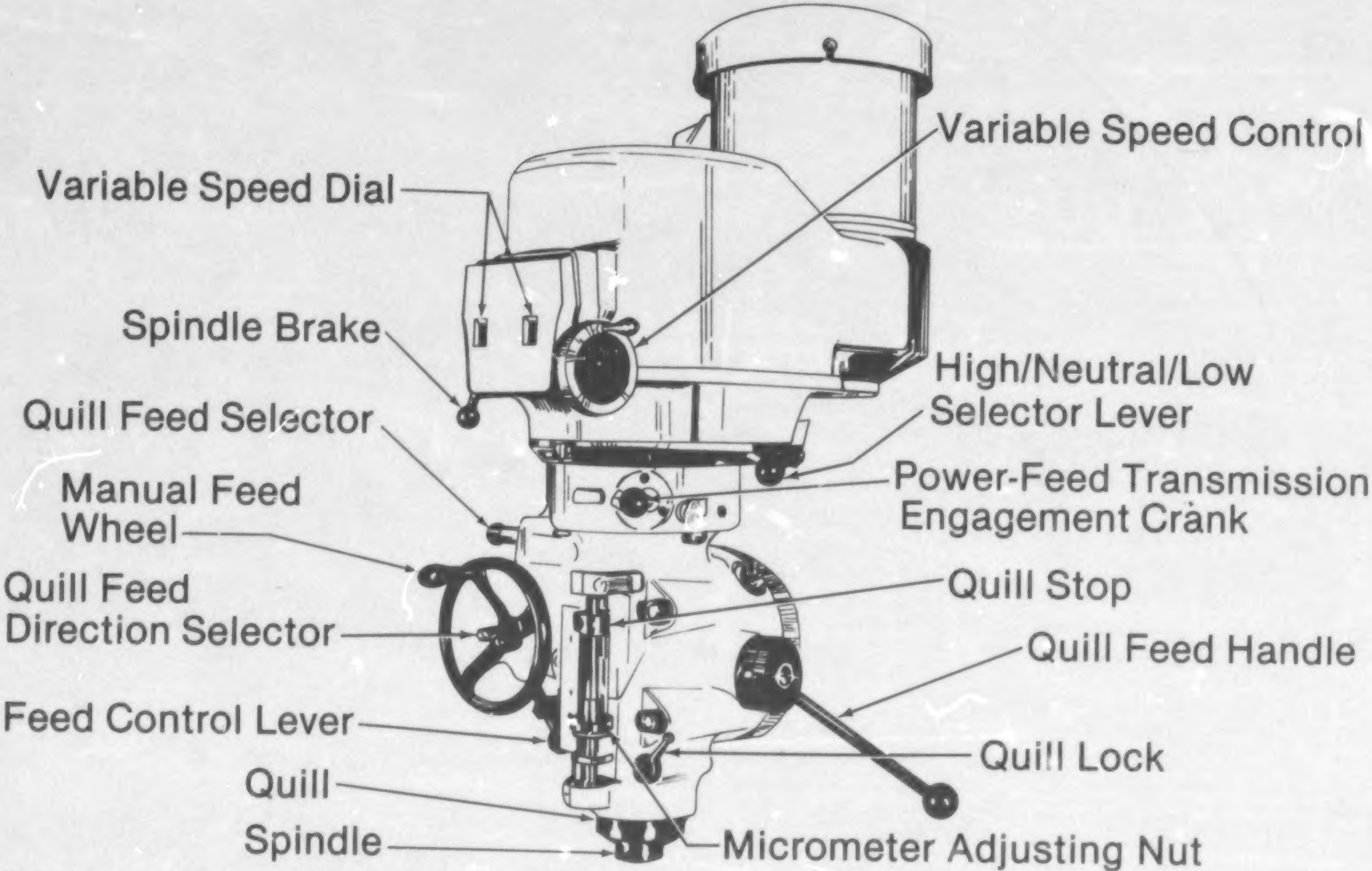
Major Parts of the Turret Mill


Drawbar
Motor
Milling Head
Speed Indicator
High/Neutral/Low Selector Lever
Spindle Power Feed
Ram
Spindle
Table
Column
Saddle
Knee
Elevating Screw Housing
Base

Adapted with permission of Bridgeport Machines.

Parts of the Milling Head


Variable Speed Control
Variable Speed Dial
Spindle Brake
High/Neutral/Low Selector Lever
Quill Feed Selector
Power-Feed Transmission Engagement Crank
Manual Feed Wheel
Quill Stop
Quill Feed Direction Selector
Quill Feed Handle
Feed Control Lever
Quill Lock
Quill
Spindle
Micrometer Adjusting Nut

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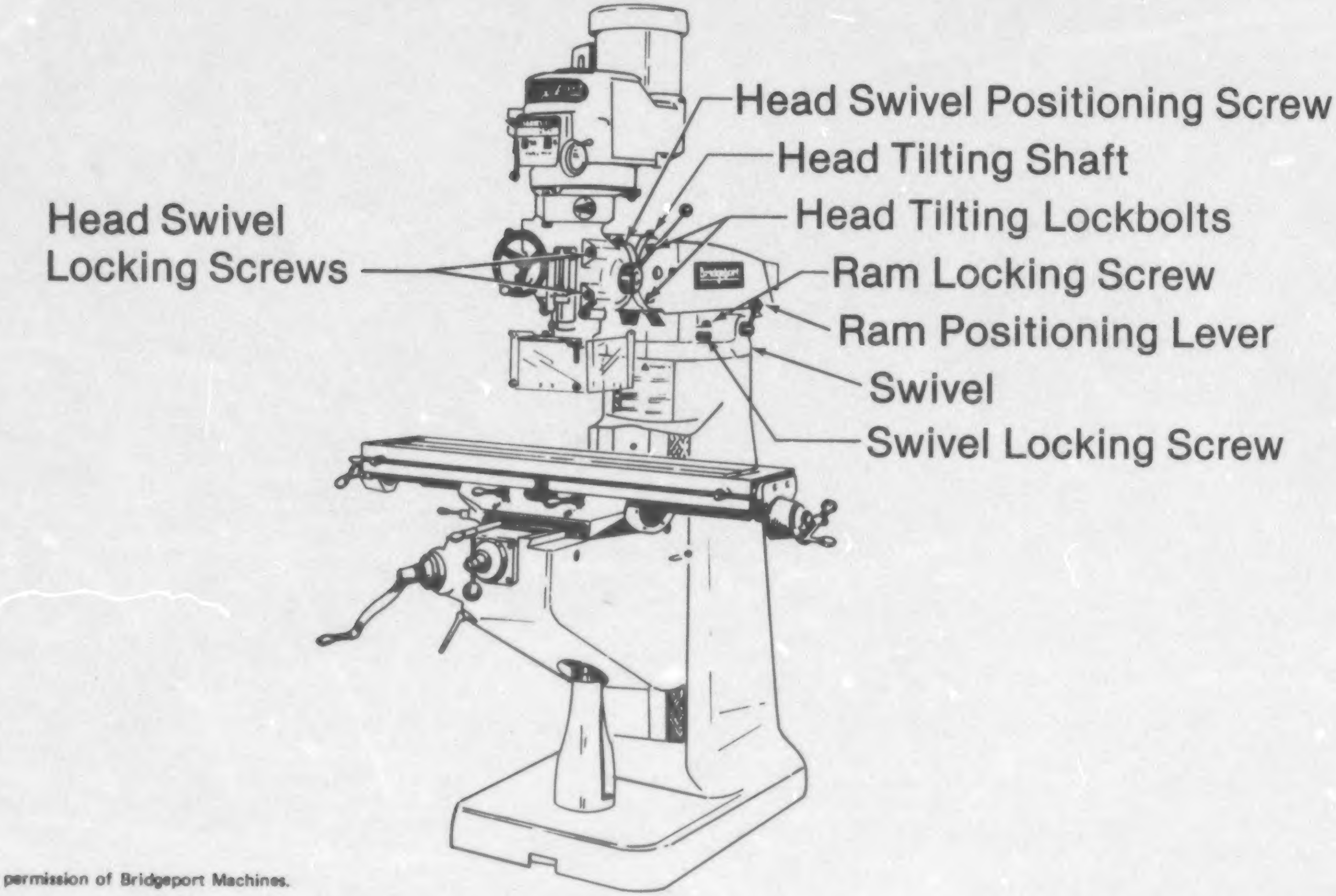
Parts of a Turret Mill Ram and Swivel


Head Swivel Positioning Screw
Head Tilting Shaft
Head Swivel Locking Screws
Head Tilting Lockbolts
Ram Locking Screw
Ram Positioning Lever
Swivel
Swivel Locking Screw

Adapted with permission of Bridgeport Machines.

Parts of a Turret Mill Table

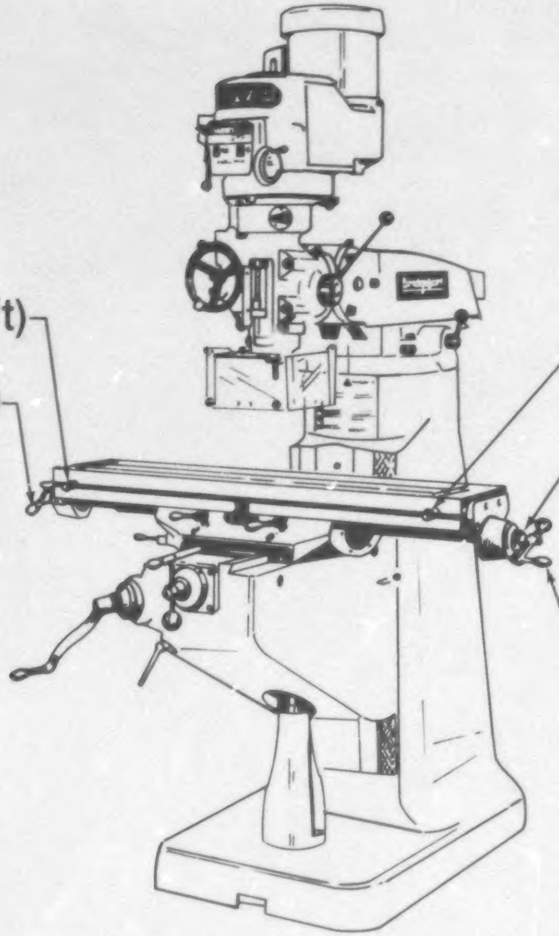


Table Stop (Left)

Table Handcrank (Left)

Table Stop (Right)

Graduated Collar (Disc)

Table Handcrank (Right)

Adapted with permission of Bridgeport Machines.

Parts of a Turret Mill Saddle and Knee

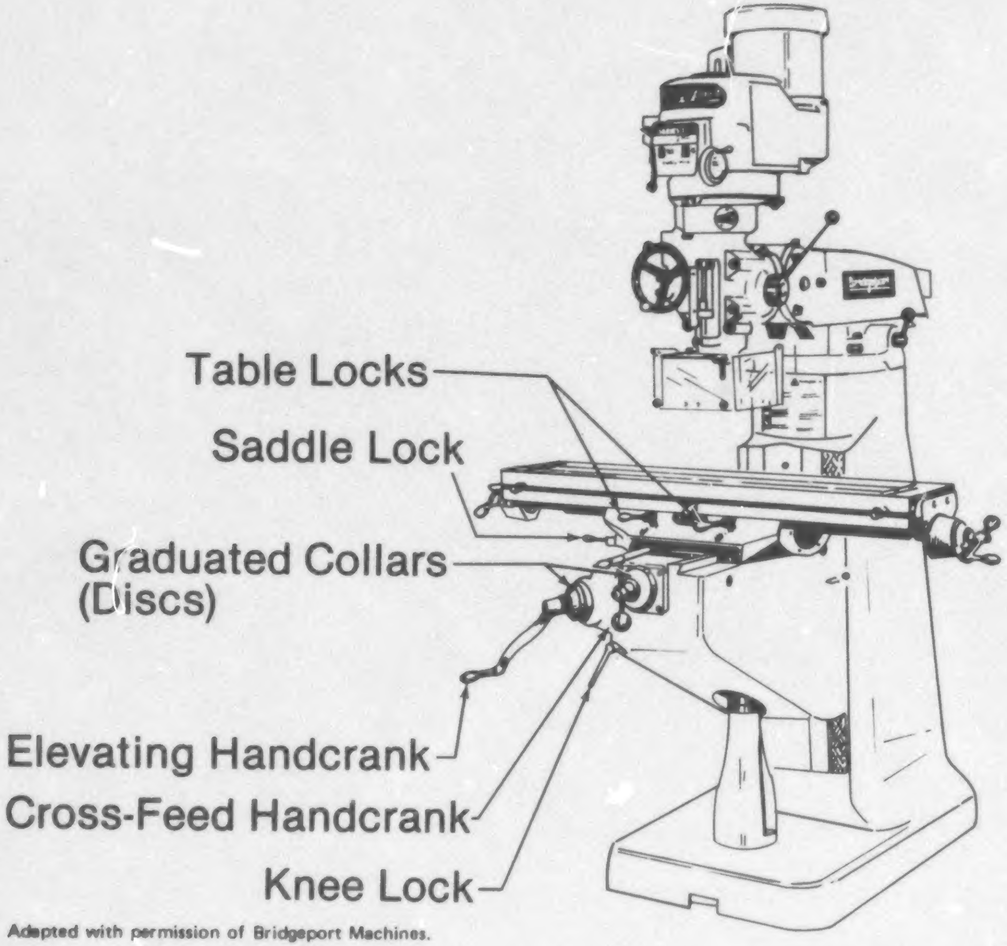
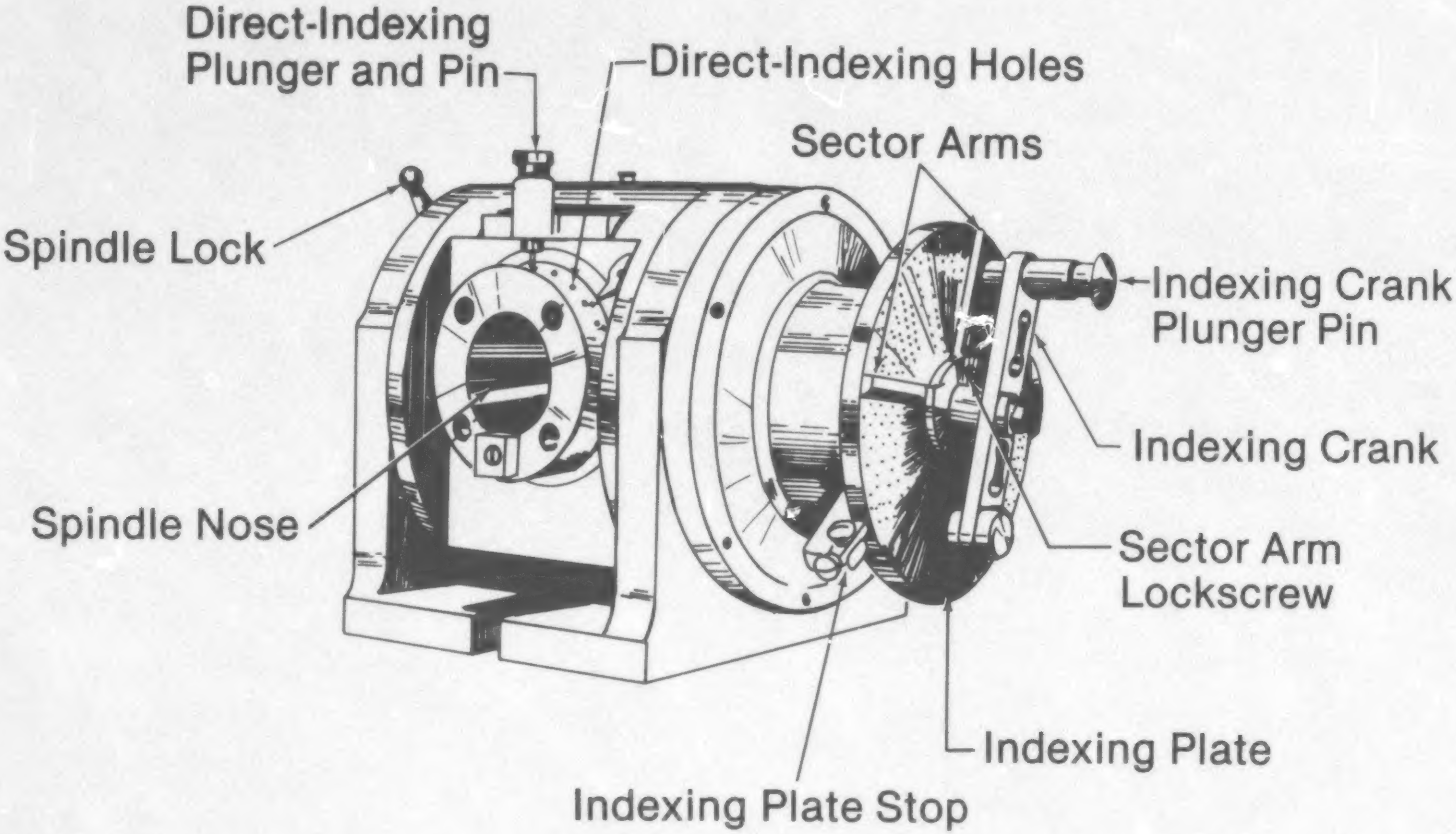


Table Locks
Saddle Lock
Graduated Collars (Discs)
Elevating Handcrank
Cross-Feed Handcrank
Knee Lock

Adapted with permission of Bridgeport Machines.

Parts of a Dividing Head


Direct-Indexing Plunger and Pin
Direct-Indexing Holes
Sector Arms
Spindle Lock
Indexing Crank Plunger Pin
Indexing Crank
Spindle Nose
Sector Arm Lockscrew
Indexing Plate
Indexing Plate Stop

INTRODUCTION TO MILLING MACHINES
UNIT I

ASSIGNMENT SHEET #1 — COMPLETE MILLING MACHINE SAFETY TEST

NAME ____ SCORE ________________

Safety awareness is like a sixth sense. Being aware of safety precautions will help you develop this sense.

Supply the key words that belong in the following blanks.

A. Use ______________________________ when handling cutters to avoid injury to hands; however, do not use around revolving cutters

B. Make sure that ______________________________ holds workpiece rigidly and that workpiece is tightly clamped to prevent slippage under cutter force, which may result in damage to cutter or workpiece or in injury to personnel

C. Make sure that __________________________ __________________________ are always keyed to arbor or held securely in holder to prevent slippage

D. Adjust ______________________________ so that workpiece moves at proper feed to prevent damage to cutter and to produce desired finish

E. ______________________________________ must be adjusted so that it ______________________________ at proper surface feet per minute to prevent damage to cutter

F. To eliminate the possibility of an accident, stop cutter rotation before taking ____________________ or making ____________________

ASSIGNMENT SHEET #1

G. ______________________________ or ______________________________ —

Feed work into cutter or against rotation of cutter when making heavy cuts

H. To avoid possible injury to hands or arms, move workpiece as far away from cutter as possible when ____

____

I. Never attempt to tighten or loosen ______________________________________

______________________________ or ______________________________ with machine power

J. Never reach over or touch ____

__________________________ with hands

K. Know location and use of all ____

____

L. Never leave a ____________________ ____________________ unattended

M. Always check machine ____

______________________________ before using machine

N. Always use ______________________________ when positioning workpiece near cutter; never use power to set up

O. When standing by machine, never ______________________________ on machine

ASSIGNMENT SHEET #1

P. Never use a machine that has a ______________________ or ______________ ______________ indicating a dangerous condition or indicating that machine needs repair

Q. Never handle ______________________ with bare hands because they can cut or burn

R. Take extreme caution to avoid forcing chips between work surfaces and to prevent injury from flying chips when using ______________________ ______________________

S. To prevent the possibility of slipping or stumbling, keep ______________________ around machine clean and free of oil, chips, and other obstructions

T. Use a hoist or ask for help when lifting ______________ ______________

U. Never operate a machine with ______________________ removed

V. Wear close-fitting clothing, with shirt tucked in and sleeves ______________ or ______________________ above elbows

W. Wear ______________________ ______________________ ______________________ ______________________ ______________________ at all times

INTRODUCTION TO MILLING MACHINES
UNIT I

ASSIGNMENT SHEET #2 — PERFORM CALCULATIONS NECESSARY FOR DIRECT AND SIMPLE INDEXING

NAME ____ SCORE ________________

Work requiring that the surface of a workpiece be divided into two or more parts with a high degree of accuracy must be done using a dividing or indexing head. The proper use of a dividing head involves calculating the required indexing correctly for the type of hole pattern used.

Calculate the simple and direct indexing required in each operation described below. For direct indexing, assume that a twenty-four-hole plate is used. To calculate simple indexing, assume that you are using a 40:1 ratio dividing head and a three-plate indexing set with the following hole patterns.

Plate 1	15-16-17-18-19-20
Plate 2	21-23-27-29-31-33
Plate 3	37-39-41-43-47-49

A. Calculate the indexing required to mill a hexagon.

Simple: ________ turns ________ holes in ________ hole pattern

Direct: ________ holes

ASSIGNMENT SHEET #2

B. Calculate the indexing required to mill a gear having twenty-five teeth using an involute gear cutter.

Simple: ________ turns ________ holes in ________ hole pattern

C. Calculate the indexing to mill a spline having eighty divisions.

Simple: ________ turns ________ holes in ________ hole pattern

D. Calculate the indexing for a gear having twenty-seven teeth.

Simple: ________ turns ________ holes in ________ hole pattern

ASSIGNMENT SHEET #2

E. Calculate the indexing for drilling twelve holes on the circumference of a pipe.

Direct: ________ holes

INTRODUCTION TO MILLING MACHINES
UNIT I

ASSIGNMENT SHEET #3 — CALCULATE MACHINE SPEED AND FEED RATES

NAME ________________________________ SCORE ______________

Cutters that are operating at the correct speed and feed will do a more efficient job without damaging the cutter.

Use the speed and feed charts following this assignment sheet to solve the following problems.

A. Perform side milling operation on aluminum bar (SAE 2024T4) using a two-flute, $^5/_8$-inch diameter end mill of high-speed steel.

1. rpm = ________________________________
2. ipm = ________________________________

B. Drill a $^1/_4$-inch diameter hole in a low-carbon steel plate (SAE 14018) 1 inch thick.

1. rpm = ________________________________
2. ipm = ________________________________

ASSIGNMENT SHEET #3

C. Cut a $^1/_2$-inch slot $^1/_4$ inch deep in a medium carbon bar (SAE 1020) with a four-flute, $^1/_2$-inch end mill of high-speed steel.

1. rpm = ______________________________
2. ipm = ______________________________

D. Drill five $^1/_2$-inch holes in a 1-inch aluminum plate (SAE 6061T6) with a $^1/_2$-inch high-speed drill.

1. rpm = ______________________________
2. ipm = ______________________________

E. Drill a $^{27}/_{64}$-inch hole and then ream to $^7/_{16}$ inch in a 1-inch steel plate (SAE 1095).

1. rpm for drilling = ______________________________
2. rpm for reaming = ______________________________

ASSIGNMENT SHEET #3

F. Mill an angle of 30 degrees on a steel bar (SAE 1035) with the side of a three-flute, 3/4-inch diameter high-speed end mill.

1. rpm for milling = ____

2. ipm = ____

ASSIGNMENT SHEET #3

MATERIAL	DRILLING								
	HIGH-SPEED STEEL TOOLS								
	SPEED sfpm (CS)	FEED-INCHES PER REVOLUTION							
		NOMINAL HOLE DIAMETER (INCHES)							
		1/16	1/8	1/4	1/2	3/4	1	1 1/2	2
Aluminum Alloys	140	0.001	-	-	-	-	-	-	-
—Wrought	275	-	0.003	0.007	0.012	0.016	0.019	0.025	0.030
Brass	140	0.001	-	-	-	-	-	-	-
330-340-353	200	-	0.003	0.006	0.010	0.013	0.016	0.021	0.025
Cast Iron	90	0.001	-	-	-	-	-	-	-
Soft	160	-	0.003	0.006	0.010	0.015	0.018	0.021	0.025
	350	-	0.003	0.006	0.010	0.014	0.017	0.021	0.025
Cast Iron	55	0.001	-	-	-	-	-	-	-
Hard	80	-	0.002	0.004	0.007	0.010	0.012	0.015	0.017
	180	-	0.002	0.004	0.007	0.010	0.012	0.015	0.017
Carbon Steel (Lo)	65	0.001	-	-	-	-	-	-	-
1010-1020	90	-	0.003	0.005	0.009	0.012	0.014	0.018	0.022
Carbon Steel (Med)	55	0.001	-	-	-	-	-	-	-
1020-1055	75	-	0.003	0.005	0.009	0.012	0.014	0.018	0.022
Carbon Steel (Hi)	-	-	-	-	-	-	-	-	-
1060-1095	45	-	0.002	0.004	0.007	0.010	0.012	0.015	0.018
Alloy Steel (Med C)	-	-	-	-	-	-	-	-	-
4130-4140	65	0.001	0.003	0.006	0.010	0.014	0.016	0.020	0.023
Tool Steel (HS)	-	-	-	-	-	-	-	-	-
M-3, M-4, M-7	35	0.001	0.002	0.003	0.005	0.007	0.008	0.011	0.013
Stainless Steel	-	-	-	-	-	-	-	-	-
300 Series	120	0.001	0.003	0.006	0.010	0.014	0.017	0.021	0.025
Stainless Steel	100	0.001	-	-	-	-	-	-	-
400 Series	125	-	0.003	0.006	0.010	0.014	0.017	0.021	0.025

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

ASSIGNMENT SHEET #3

MATERIAL	SLAB MILLING DEPTH OF CUT (INCHES)	HIGH-SPEED STEEL TOOL SPEED sfpm (CS)	 FEED IN/TOOTH
Aluminum Alloys —Wrought	0.250	650	0.014
	0.025	900	0.012
Brass 330-340-353	0.125	430	0.016
	0.025	525	0.014
Cast Iron Soft	0.150	175	0.012
	0.025	225	0.010
Cast Iron Hard	0.150	60	0.008
	0.025	80	0.006
Carbon Steel (Lo) 1010-1020	0.150	195	0.008
	0.025	220	0.006
Carbon Steel (Med) 1030-1055	0.150	90	0.006
	0.025	120	0.005
Carbon Steel (Hi) 1060-1095	0.150	80	0.006
	0.025	110	0.005
Alloy Steel (Med C) 4130-4140	0.150	100	0.008
	0.025	140	0.006
Tool Steel (HS) M-3, M-4, M-7	0.125	55	0.006
	0.025	70	0.005
Stainless Steel 300 Series	0.150	125	0.007
	0.025	155	0.006
Stainless Steel 400 Series	0.150	125	0.006
	0.025	165	0.005

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

ASSIGNMENT SHEET #3

FACE MILLING						
		HIGH-SPEED STEEL TOOL		CARBIDE TOOL		
				SPEED-sfpm (CS)		
MATERIAL	DEPTH OF CUT (INCHES)	SPEED sfpm (CS)	FEED IN/TOOTH	BRAZED	THROWAWAY	FEED IN/TOOTH
Aluminum Alloys —Wrought	0.250	800	0.022	1500	1800	0.020
	0.025	1200	0.010	1800	2000	0.010
Brass 330-340-353	0.125	450	0.020	900	990	0.018
	0.025	550	0.010	1200	1320	0.010
Cast Iron Soft	0.150	185	0.016	475	525	0.020
	0.025	235	0.010	630	695	0.010
Cast Iron Hard	0.150	65	0.010	300	330	0.010
	0.025	85	0.008	400	440	0.008
Carbon Steel (Lo) 1010-1020	0.150	140	0.012	450	490	0.014
	0.025	190	0.008	550	590	0.008
Carbon Steel (Med) 1030-1055	0.150	100	0.010	375	415	0.012
	0.025	125	0.006	450	500	0.008
Carbon Steel (Hi) 1060-1095	0.150	80	0.009	300	330	0.010
	0.025	105	0.005	390	420	0.006
Alloy Steel (Med C) 4130-4140	0.150	120	0.012	370	410	0.014
	0.025	150	0.008	490	530	0.008
Tool Steel (HS) M-3, M-4, M-7	0.125	60	0.007	220	240	0.010
	0.025	75	0.004	290	320	0.008
Stainless Steel 300 Series	0.150	130	0.010	375	415	0.014
	0.025	160	0.008	500	515	0.008
Stainless Steel 400 Series	0.150	135	0.008	400	475	0.010
	0.025	175	0.006	550	610	0.008

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

ASSIGNMENT SHEET #3

MATERIAL	SIDE AND SLOT MILLING (ARBOR-MOUNTED CUTTERS)				
	DEPTH OF CUT (INCHES)	HIGH-SPEED STEEL TOOL		CARBIDE TOOL	
		SPEED sfpm (CS)	FEED IN/TOOTH	SPEED sfpm (CS)	FEED IN/TOOTH
Aluminum Alloys	0.250	400	0.010	1200	0.010
—Wrought	0.050	600	0.012	1500	0.020
Brass	0.250	250	0.008	600	0.007
330-340-353	0.050	300	0.010	700	0.009
Cast Iron	0.250	150	0.006	375	0.007
Soft	0.050	165	0.009	425	0.009
Cast Iron	0.250	75	0.005	250	0.007
Hard	0.050	85	0.007	300	0.009
Carbon Steel (Lo)	0.250	85	0.005	300	0.007
1010-1020	0.050	100	0.007	350	0.009
Carbon Steel (Med)	0.250	50	0.005	230	0.007
1030-1055	0.050	65	0.007	250	0.009
Carbon Steel (Hi)	0.250	40	0.005	200	0.007
1060-1095	0.050	55	0.007	215	0.009
Alloy Steel (Med C)	0.250	45	0.005	240	0.007
4130-4140	0.050	65	0.007	270	0.009
Tool Steel (HS)	0.250	35	0.004	185	0.004
M-3, M-4, M-7	0.050	50	0.005	195	0.005
Stainless Steel	0.250	95	0.005	275	0.007
300 Series	0.050	110	0.007	300	0.009
Stainless Steel	0.250	75	0.005	300	0.007
400 Series	0.050	90	0.007	310	0.009

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

ASSIGNMENT SHEET #3

MATERIAL	DEPTH OF CUT (INCHES)	END MILLING-PERIPHERAL									
		HIGH-SPEED STEEL TOOLS					CARBIDE TOOL				
		SPEED sfpm	FEED-IN/TOOTH				SPEED sfpm	FEED-IN/TOOTH			
			CUTTER DIA. (INCHES)					CUTTER DIA. (INCHES)			
			1/4	1/2	3/4	1 to 2		1/4	1/2	3/4	1 to 2
Aluminum Alloys —Wrought	0.050	600	0.003	0.005	0.008	0.010	1000	0.003	0.005	0.008	0.010
	0.015	800	0.002	0.003	0.005	0.007	1300	0.002	0.003	0.005	0.007
Brass 330-340-353	0.050	375	0.003	0.005	0.008	0.010	750	0.003	0.005	0.008	0.010
	0.015	450	0.002	0.003	0.005	0.007	900	0.002	0.003	0.005	0.007
Cast Iron Soft	0.050	145	0.002	0.004	0.006	0.008	525	0.002	0.005	0.009	0.010
	0.015	180	0.001	0.002	0.005	0.007	625	0.001	0.003	0.007	0.009
Cast Iron Hard	0.050	70	0.002	0.0025	0.003	0.004	250	0.002	0.003	0.004	0.006
	0.015	90	0.001	0.0015	0.002	0.003	300	0.001	0.002	0.003	0.005
Carbon Steel (Lo) 1010-1020	0.050	160	0.002	0.003	0.005	0.006	400	0.0025	0.004	0.006	0.008
	0.015	210	0.001	0.002	0.004	0.005	520	0.0015	0.0035	0.005	0.007
Carbon Steel (Med) 1030-1055	0.050	85	0.002	0.003	0.004	0.005	330	0.002	0.003	0.005	0.007
	0.015	110	0.001	0.002	0.003	0.004	430	0.001	0.002	0.004	0.005
Carbon Steel (Hi) 1060-1095	0.050	70	0.001	0.002	0.004	0.005	275	0.002	0.003	0.005	0.006
	0.015	90	0.0007	0.0015	0.003	0.004	360	0.001	0.002	0.004	0.005
Alloy Steel (Med C) 4130-4140	0.050	90	0.002	0.003	0.004	0.005	350	0.0025	0.004	0.006	0.007
	0.015	120	0.001	0.002	0.003	0.004	455	0.0015	0.003	0.005	0.006
Tool Steel (HS) M-3, M-4, M-7	0.050	60	0.001	0.002	0.003	0.004	225	0.0015	0.0025	0.004	0.005
	0.015	75	0.0007	0.001	0.002	0.003	280	0.001	0.0015	0.0025	0.004
Stainless Steel 300 Series	0.050	135	0.001	0.002	0.004	0.005	350	0.001	0.002	0.005	0.007
	0.015	175	0.0005	0.001	0.003	0.004	455	0.0005	0.001	0.004	0.006
Stainless Steel 400 Series	0.050	125	0.001	0.002	0.004	0.005	350	0.001	0.002	0.005	0.007
	0.015	160	0.0005	0.001	0.003	0.006	455	0.0005	0.001	0.004	0.006

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

ASSIGNMENT SHEET #3

END MILLING-SLOTTING

MATERIAL	DEPTH OF CUT (INCHES)	HIGH-SPEED STEEL TOOLS				
		SPEED sfpm (CS)	FEED-IN/TOOTH			
			CUTTER DIA. (INCHES)			
			1/4	1/2	3/4	1 to 2
Aluminum Alloys	0.250	250	0.001	0.002	0.003	0.004
—Wrought	0.050	280	0.0005	0.001	0.002	0.003
Brass	0.250	225	-	0.003	0.005	0.007
330-340-353	0.050	250	0.0015	0.002	0.003	0.005
Cast Iron	0.250	85	-	-	0.003	0.004
Soft	0.050	95	0.001	0.0015	0.002	0.003
Cast Iron	0.250	40	-	-	0.0015	0.002
Hard	0.050	45	0.0005	0.0007	0.001	0.0015
Carbon Steel (Lo)	0.250	100	-	-	0.0025	0.003
1010-1020	0.050	110	0.001	0.0015	0.002	0.0025
Carbon Steel (Med)	0.250	75	-	-	0.002	0.0025
1030-1055	0.050	85	0.0005	0.001	0.0015	0.002
Carbon Steel (Hi)	0.250	55	-	-	0.002	0.0025
1060-1095	0.050	65	0.0005	0.001	0.0015	0.002
Alloy Steel (Med C)	0.250	70	-	-	0.002	0.0025
4130-4140	0.050	75	0.0005	0.001	0.0015	0.002
Tool Steel (HS)	0.250	35	-	-	0.0015	0.002
M-3, M-4, M-7	0.050	40	0.0005	0.0007	0.001	0.0015
Stainless Steel	0.250	80	-	-	0.002	0.0025
300 Series	0.050	90	0.0005	0.001	0.0015	0.002
Stainless Steel	0.250	75	-	-	0.002	0.0025
400 Series	0.050	85	0.0005	0.001	0.0015	0.002

(NOTE: Figures given are representative. For more complete listings, refer to machinist handbook.)

INTRODUCTION TO MILLING MACHINES
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Rags

B. Setup

C. Cutting tools

D. Feed

E. Cutter, rotates

F. Measurements, adjustments

G. Conventional, up-milling

H. Changing parts

I. Arbor nut, drawbar

J. Revolving cutter

K. Machine controls

L. Running machine

M. Travel levers

N. Handcranks

O. Lean

P. Sign, warning tag

Q. Chips

R. Compressed air

S. Area

T. Heavy objects

U. Guards

ANSWERS TO ASSIGNMENT SHEETS

V. Buttoned, rolled

W. Safety glasses with side shields

Assignment Sheet #2

A. Simple: 6 turns 10 holes in the 15-hole pattern

Direct: 4 holes in direct index plate

B. Simple: 1 turn 9 holes in the 15-hole pattern

C. Simple: 0 turns 8 holes in the 16-hole pattern

D. Simple: 1 turn 13 holes in the 27-hole pattern

E. Direct: 2 holes in direct index plate

Assignment Sheet #3

A. 1. 3,840

2. 46.08 to 53.76

B. 1. 1,040

2. 5.2

C. 1. 400

2. 0.6

D. 1. 1,120

2. 13.44

E. 1. 427

2. 213

F. 1. 453

2. 1.8

INTRODUCTION TO MILLING MACHINES
UNIT I

JOB SHEET #1 — CLEAN AND LUBRICATE A HORIZONTAL MILL

I. Equipment and materials

- A. Milling machine and operator's manual
- B. Clean rags
- C. Brush
- D. Grease gun with recommended way lube
- E. Oil can (pump-type) with recommended oil
- F. Solvent

II. Procedure for cleaning

(NOTE: Before cleaning, all feed locks should be in disengaged position.)

- A. Secure power switch in OFF position
- B. Use elevating handcrank to lower knee to lowest position
- C. Crank saddle and table fully forward
- D. Brush chips from bed, T-slots, ways, and other places where they may have accumulated
- E. Clean all exposed areas with rag and solvent; wipe dry with clean rag
- F. Remove chip screens from table and base
- G. Clean chip screens with solvent; replace
- H. Crank up knee
- I. Crank saddle and table fully toward column
- J. Clean ways and base with solvent; wipe dry
- K. Apply a thin coat of way lube to all unpainted metal surfaces

  (NOTE: Felt wipers should be removed, cleaned in solvent, or replaced yearly; however, they should be soaked in way lube before being reinstalled.)

  (CAUTION: Check with instructor before removing felt wipers.)

III. Procedure for lubrication

- A. Visually check all sight gauges

JOB SHEET #1

B. Check all reservoirs

C. Lubricate fittings as required

(NOTE: Older machines have grease fittings; most of the newer machines have a one-shot lubrication plunger that pushes oil to all the proper places.)

(CAUTION: Before adding oil to reservoir, check the operator's manual. You should find a chart and picture to show lubrication points, and frequency and type of lubricant to be used. See Figures 54 and 55.)

FIGURE 54

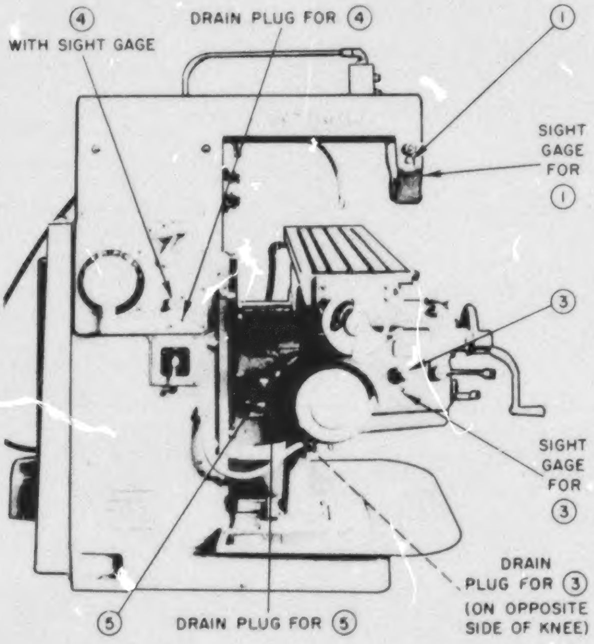
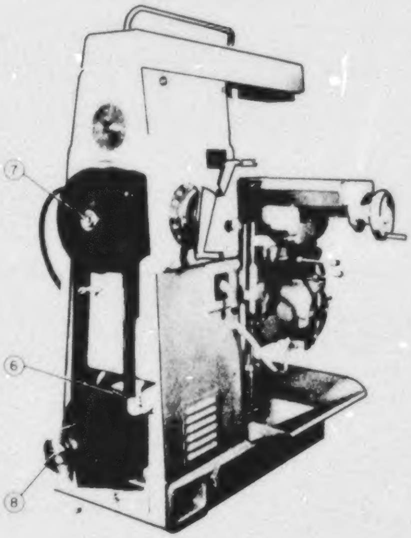

④
WITH SIGHT GAGE
DRAIN PLUG FOR ④
①
SIGHT GAGE FOR ①
③
SIGHT GAGE FOR ③
DRAIN PLUG FOR ③ (ON OPPOSITE SIDE OF KNEE)
⑤
DRAIN PLUG FOR ⑤

FIGURE 55



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(NOTE: Numbers on Figures 54 and 55 are referenced on lubrication chart on the following page.)

JOB SHEET #1

LUBRICATION CHART

Lubricate all principal points as listed below before starting machine. Periodic and thorough lubrication with correct lubricant, as specified, will help maintain the long life and accuracy built into machine. The intervals listed are based on a normal eight-hour day. (See Figures 54 and 55).

STATION NUMBER	PART LUBRICATED	TYPE LUBRICANT	FREQUENCY	INSTRUCTIONS
1	Arbor bearing collar	CMMCo. Specification P-55. Good-quality rust and oxidation inhibited paraffin base oil. Viscosity 200-220 S.U.S. at 100°F.	At low limit	Automatic lubrication. Keep filled above low limit on gauge. 1 pint.
3	Front bracket and motor drive gearing		At low limit	Fill to top of elbow. Keep sight gauge filled at all times. Drain and refill every six months.
4	Spindle drive gears and other parts in column		At low limit	Keep filled above low limit on gauge. Drain and refill every six months.
5	Table, saddle, and knee ways; knee bearings		At low limit	Pull out handle full length of stroke, allowing plunger to return itself to position. Pull plunger three times and perform this lubrication twice daily. When plunger returns without pressure resistance, the oil has reached its low limit and should be filled.
6	Vertical screw	CMMCo. Specification P-63. Good grade low-viscosity lead naphthenate compounded oil having excellent water-repellent characteristics. Viscosity 300 to 360 S.U.S. at 100°F.	At low limit	Keep filled to neck of fill pipe. *Fill when knee is at bottom of screw.*
7 and 8	Motor sheave and pulley sheave	CMMCo. Specification P-64. Premium-quality, general-purpose, No. 2 lithium-based grease.	Weekly	Inject about ½ ounce of grease through nipple with hand gun (two to three shots). NOTE: Exert caution not to over-grease.

(NOTE: When lubricating points 7 and 8, run the speed range from low to high and back again several times to assure uniform lubrication.)

Chart used with permission of Cincinnati Milacron.

D. Lubricate other mill parts as required

(NOTE: If the specified oil is not in tool room, check with instructor as to the approved substitute you should use.)

E. Clean work area and put away equipment and materials

INTRODUCTION TO MILLING MACHINES
UNIT I

JOB SHEET #2 — CLEAN AND LUBRICATE A VERTICAL MILL

I. Equipment and materials

- A. Vertical milling machine with operator's manual
- B. Clean rags
- C. Brush
- D. Solvent
- E. Grease gun with recommended way lube
- F. Oil can (pump-type) with recommended oil

II. Procedure for cleaning

(NOTE: Before cleaning, all feed locks should be in disengaged position.)

- A. Secure power in OFF position
- B. Use handcrank to crank table to its lowest position
- C. Crank cross-feed handcrank to move saddle toward you
- D. Brush chips from ways, bed, T-slots, and other places where they may have accumulated
- E. Clean all exposed areas with rag and solvent; wipe dry with clean rag
- F. Crank in saddle
- G. Clean ways on front of knee with rag and solvent; wipe dry
- H. Apply a thin coat of way lube to all unpainted metal surfaces
- I. Crank up knee

  (CAUTION: When raising the knee, be careful not to crank the elevating screw out of its threaded area. The knee should not be elevated any higher than the column ways; otherwise, you stand a chance of damaging the brass threads in the elevating housing.)

- J. Clean base with rag and solvent; wipe dry

JOB SHEET #2

III. Procedure for lubrication

- A. Consult operator's manual for lubrication chart and frequency
- B. Lubricate machine as required

  (NOTE: Some of the newer machines have a one-shot lubrication pump. This pump forces oil from the reservior to all parts of the machine except the head.)

- C. Wipe off excess oil and grease with rag
- D. Clean work area and put away equipment and materials

INTRODUCTION TO MILLING MACHINES
UNIT I

TEST

NAME ____________________________ SCORE ______________

1. Match terms associated with milling machines to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a. Movable metal stops that are part of tripping mechanism used to control power movement of table, saddle, or knee by tripping the power-feed mechanism

_____b. Device that shows the required level of a lubricant for visual inspection

_____c. Parts of milling machine that support and move table up and down by elevating crank

_____d. Method of designating milling machine spindles

_____e. Amount of lost motion (play) in moving parts when reversing direction of feed in a screw or gear

_____f. Steel bolt that goes through spindle, screws into arbor or adapter, pulls arbor into spindle taper, and holds it in place with a locknut

_____g. Round machine table on which a workpiece is secured and moved in a circular path, rotating workpiece to desired angle in relation to cutter

_____h. Metal lugs bolted to spindle to transmit power to arbor or adapter

_____i. Machining flat, angular, circular, and tapered surfaces with a revolving cutter

_____j. Movement of table right or left through saddle dovetails

_____k. Part of machine on which work or work-holding devices are mounted; moves longitudinally through saddle

1. Milling
2. Knee and column
3. Saddle
4. Table
5. Trip dogs
6. Driving lugs
7. Traversal
8. Dividing head
9. Rotary table
10. Override
11. Sight gauge
12. Standard machine taper
13. Drawbar
14. Backlash
15. Longitudinal

TEST

______l. Mechanism used to divide the circumference of a workpiece into a given number of spaces for milling or drilling

______m. Holds table and moves in and out traversely on knee; mounted to knee

______n. Lateral or crosswise movement of saddle

______o. Device or process that allows machine to operate outside the limits set by selectors or other machine parts

2. Name five types of milling machines

a. ______________________________

b. ______________________________

c. ______________________________

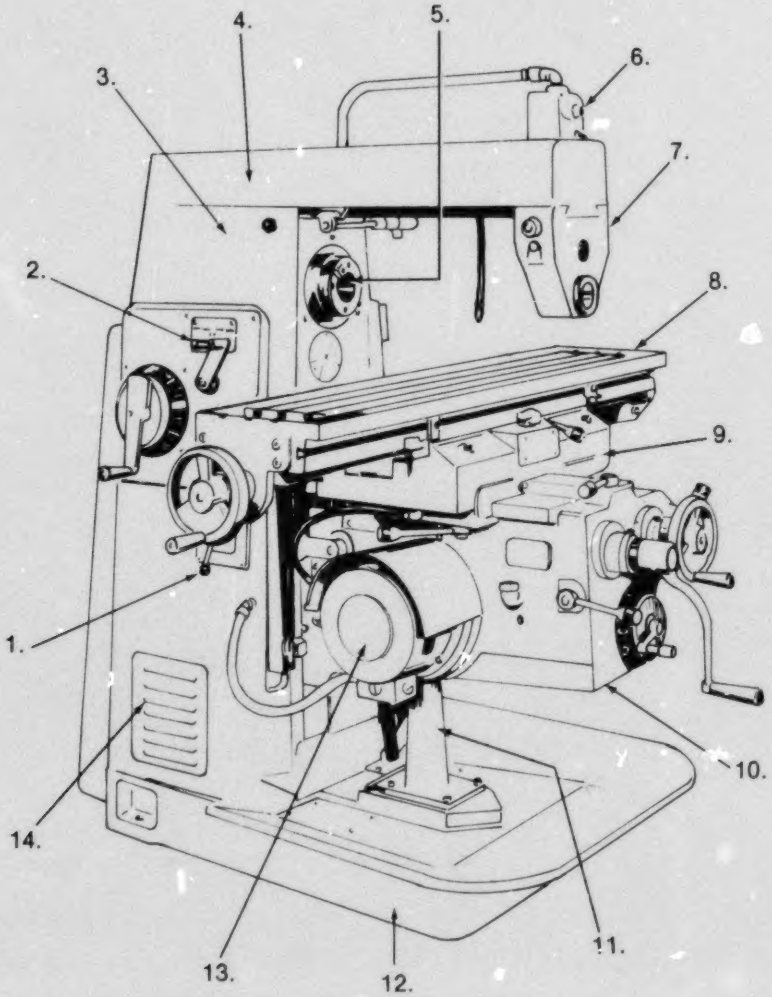
d. ______________________________

e. ______________________________

TEST

3. Identify major parts of the horizontal knee-and-column mill. Write the correct numbers in the blanks.

______a. Overarm
______b. Overarm support
______c. Spindle
______d. Base
______e. Spindle reversing lever
______f. Knee motor drive
______g. Table
______h. Elevating screw housing
______i. Column
______j. Saddle
______k. High/neutral/low selector lever
______l. Knee
______m. Start/stop switches
______n. Spindle motor cover



TEST

4. Match specific parts of the horizontal mill to their correct uses. Write the correct numbers in the blanks. Continued on the next page.

Column

_____a. Guide and support knee, saddle, and table

_____b. Sets direction of spindle rotation

_____c. Allows access to spindle motor for maintenance

_____d. Guides movement of ram-type overarm

_____e. Supports column, serves as reservoir for coolant, and provides base for elevating screw

_____f. Aligns and drives different kinds of arbors

_____g. Secure overarm to column

_____h. Permits speed mechanisms to be used in two speed ranges

_____i. Selects revolutions per minute (rpm) at which spindle turns

1. Ways
2. Spindle
3. Base
4. Overarm slide
5. Spindle motor cover
6. Spindle reversing lever
7. High/neutral/low selector lever
8. Spindle speed indicating dial
9. Overarm lockbolts

Knee

_____a. Provides for manual traverse travel of table and saddle

_____b. Provides support for knee; houses elevating screw mechanism

_____c. Overrides setting of feed indicating dial, allowing table to move at a higher rate of feed

_____d. Moves knee assembly up or down by means of elevating screw

_____e. Indicate amount of cross-feed movement or elevating movement in thousandths of an inch

_____f. Moves knee assembly up or down by power at rate of feed set by feed dial

1. Power elevating lever
2. Cross-feed handwheel
3. Knee lock
4. Feed indicating dial
5. Elevating crank
6. Elevating screw housing
7. Rapid traverse lever
8. Knee drive motor
9. Graduated collars

TEST

______g. Locks knee to column

______h. Selects rate at which machine feeds in longitudinal, traversal, or vertical travel

______i. Provides power movement to knee for elevating, traversal, and longitudinal movements

Saddle

______a. Engages power feed for longitudinal travel of table

______b. Lock table in position

______c. Slide on knee; guide table by means of dovetails

______d. Locks saddle to knee

1. Table clamp screws
2. Ways
3. Saddle lock
4. Longitudinal-feed lever

Table

______a. Indicates amount of table movement in thousandths of an inch

______b. Slide in slots on table, are adjusted to desired length of feed, and stop feed when contact is made with table engaging lever

______c. Moves table by hand

______d. Limit maximum movement of table

______e. Allow work-holding devices to be secured to table

1. Trip dogs
2. Graduated collar
3. Longitudinal-feed handwheel
4. T-slots
5. Positive end stops

TEST

5. Identify major parts of the turret mill. Write the correct numbers in the blanks.

______a. Drawbar

______b. Column

______c. Ram

______d. Base

______e. High/neutral/low selector lever

______f. Table

______g. Motor

______h. Saddle

______i. Milling head

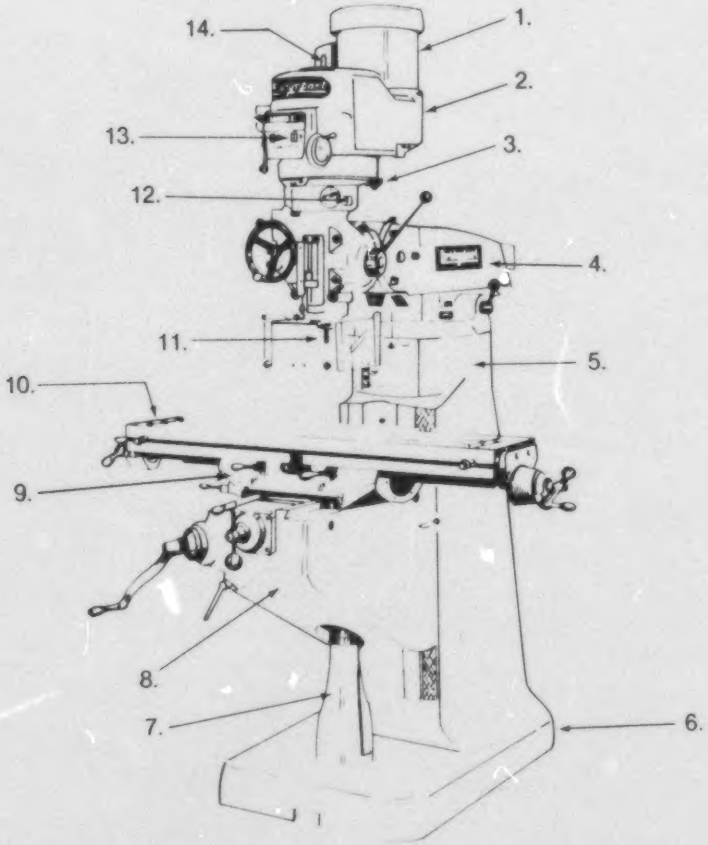
______j. Knee

______k. Elevating screw housing

______l. Spindle power feed

______m. Spindle

______n. Speed indicator



TEST

6. Match specific parts of the turret mill to their correct uses. Write the correct numbers in the blanks. Continued on the next page.

Milling Head

_____a. Houses spindle and bearing; moves in or out of mill head for drilling, boring, and other operations

_____b. Engages or disengages power feed of quill

_____c. Feeds quill by hand

_____d. Indicates speed of spindle in high or low range

_____e. Feeds quill during manual movement

_____f. Increases or decreases spindle speed

_____g. Locks spindle to allow tightening or loosening of drawbar

_____h. Houses cutter holder and transmits rotary motion to cutter

_____i. Locks quill

_____j. Sets speed range of spindle

_____k. Sets rate of feed for quill

_____l. Starts and stops quill

_____m. Selects direction of feed for quill (up or down)

_____n. Moves with quill, trips feed control lever when depth is reached, and stops power quill movement

_____o. Adjusts quill movement to a precise depth; graduated in thousandths of an inch

1. Variable speed dial
2. Spindle brake
3. Quill feed selector
4. Manual feed wheel
5. Feed control lever
6. Quill
7. Spindle
8. Quill lock
9. Variable speed control
10. Quill stop
11. Quill feed handle
12. High/neutral/low selector lever
13. Power-feed transmission engagement crank
14. Quill feed direction selector
15. Micrometer adjusting nut

TEST

Ram and swivel

______a. Secure head at set angle perpendicular to ram axis

______b. Moves ram back and forth in swivel

______c. Moves head right or left

______d. Secures swivel in position

______e. Lock position of head at set angle along ram axis

______f. Secures ram in position

______g. Allows head to be swiveled in (toward column) or out (away from column)

______h. Allows ram and working head to be rotated to different positions

1. Ram positioning lever
2. Ram locking screw
3. Swivel
4. Swivel locking screw
5. Head tilting shaft
6. Head tilting lockbolts
7. Head swivel positioning screw
8. Head swivel locking screws

Table

______a. Limit movement of table

______b. Engages power-feed mechanism

______c. Indicates amount of table movement in thousandths of an inch

______d. Indicates and selects rate of table feed for power movement

______e. Move table longitudinally

1. Table handcranks
2. Power-feed control lever
3. Table stops
4. Power-feed attachment
5. Graduated collar

Saddle and knee

______a. Lock position of table in saddle

______b. Locks position of saddle on knee

______c. Indicate amount of cross-feed movement or elevating movement in thousandths of an inch

______d. Moves saddle in and out with micrometer accuracy

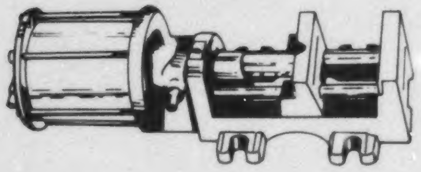
______e. Moves knee up and down

______f. Locks position of knee to column

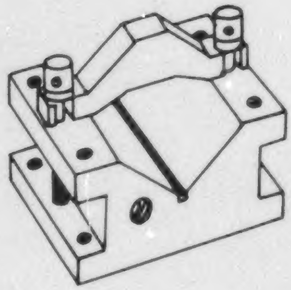
1. Saddle lock
2. Graduated collars
3. Knee lock
4. Elevating handcrank
5. Cross-feed handcrank
6. Table locks

TEST

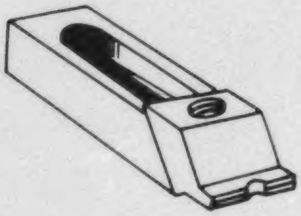
7. Label work-holding devices. Write the correct names in the blanks.



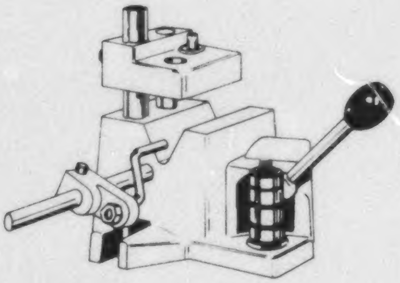
a. ______________________________



b. ______________________________



c. ______________________________



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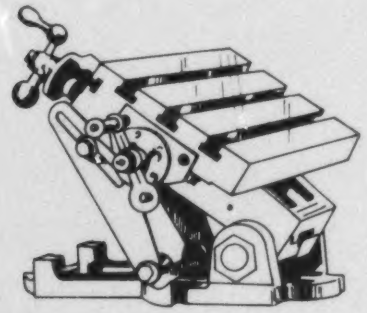

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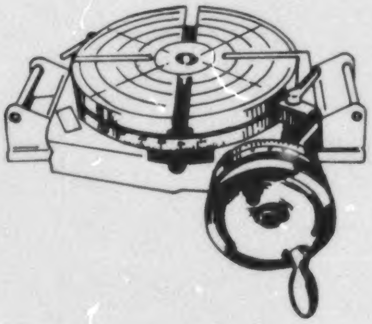
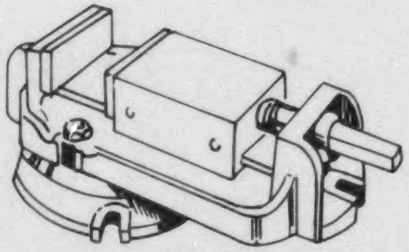
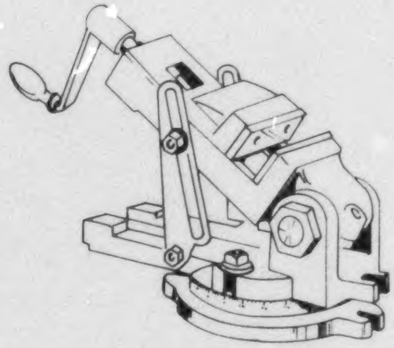


f. ______________________________

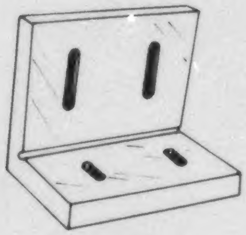
TEST



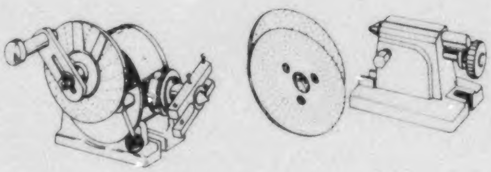
g. ______________________________



h. ______________________________



i. ______________________________

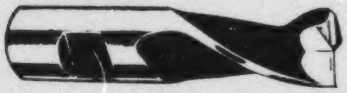


j. ______________________________

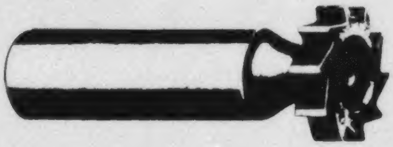
TEST

8. Identify cutting tools. Write the correct names in the blanks.

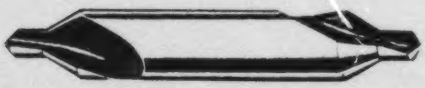
Single-end, two-flute helical end mill
Ball-nose end mill
Woodruff keyseat cutter
Counterbore with pilot
Straight-shank drill
Reamer
Helical mill cutter
Staggered-tooth mill cutter
Corner-rounding end mill (radius-cutting end mill)
Single-angle mill cutter
Plain metal-slitting saw
Corner-rounding mill cutter (radius cutter)
Double-end, two-flute helical end mill
Four-flute end mill
Roughing end mill
Countersink
Combination drill and countersink (center drill)
Plain mill cutter
Side mill cutter
Concave mill cutter
Convex mill cutter
Involute gear cutter
Double-angle mill cutter
Insert-type end mill
Dovetail-cutting end mill
Shell mill cutter



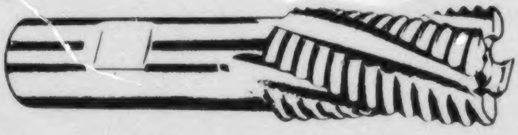
a. ____________________



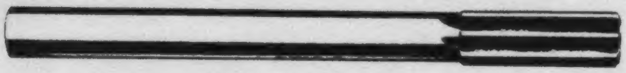
b. ____________________



c. ____________________

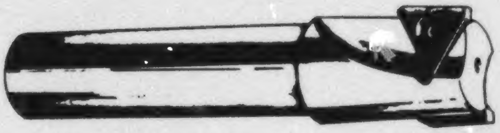


d. ____________________

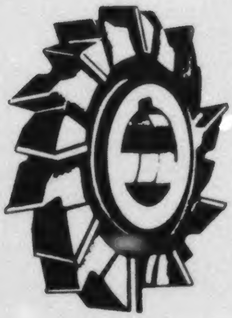


e. ____________________

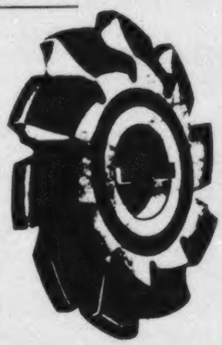
TEST



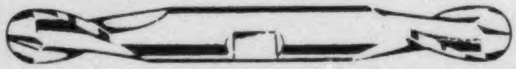
f. ______________________________



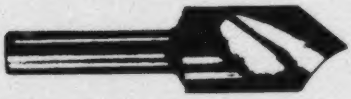
g. ______________________________



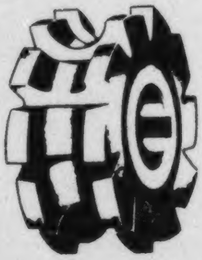
h. ______________________________



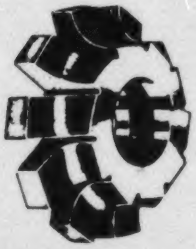
i. ______________________________



j. ______________________________

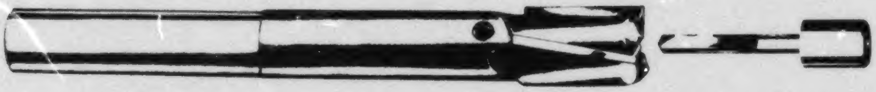


k. ______________________________

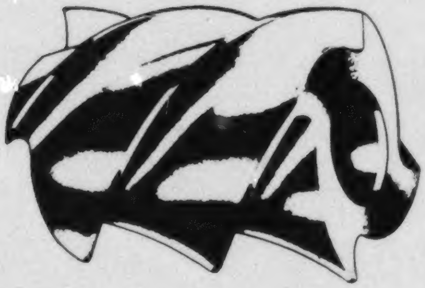


l. ______________________________

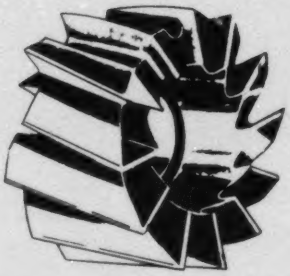
TEST



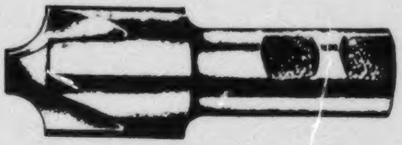
m. ____________________



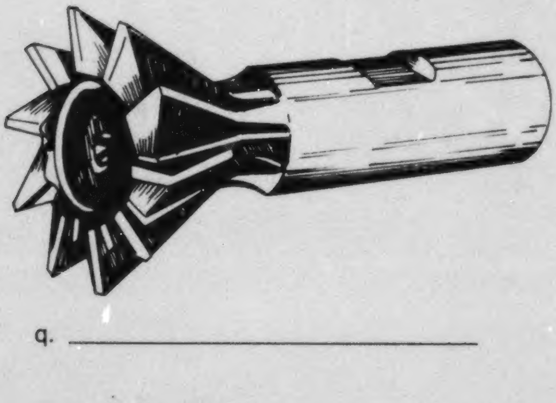
n. ____________________



o. ____________________

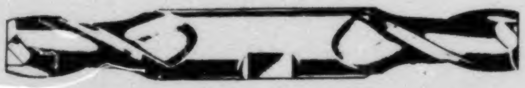


p. ____________________

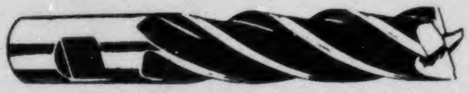


q. ____________________

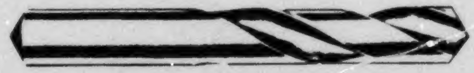
TEST



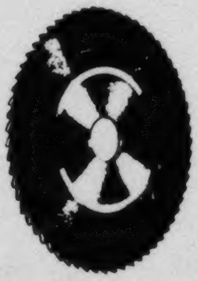
r. ______________________________



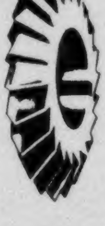
s. ______________________________



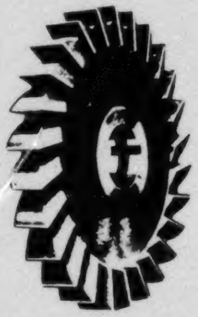
t. ______________________________



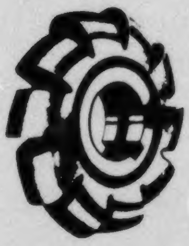
u. ____________________



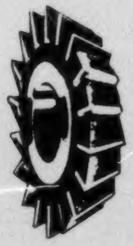
v. ____________________



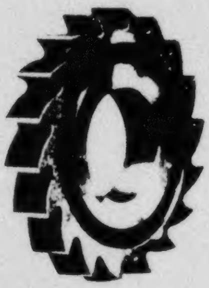
w. ____________________



x. ____________________



y. ____________________

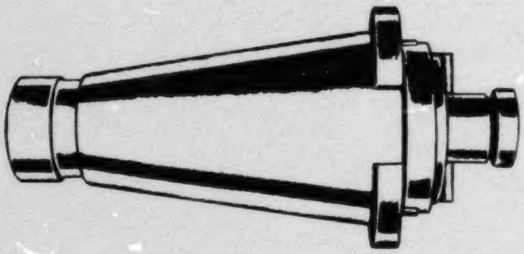


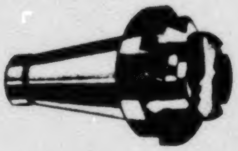
z. ____________________

TEST

9. Identify toolholders for cutting tools. Write the correct names in the blanks.

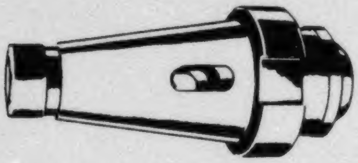
End mill holder
Collet
Shell mill arbor
Style C arbor
Taper adapter
Style A arbor
Style B arbor

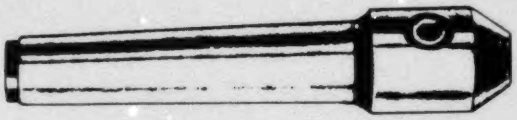




a. ______________________________

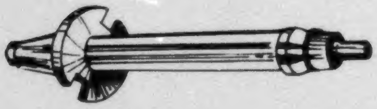
b. ______________________________

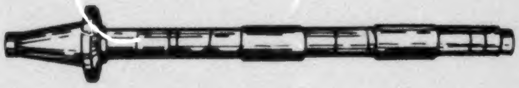




c. ______________________________

d. ______________________________

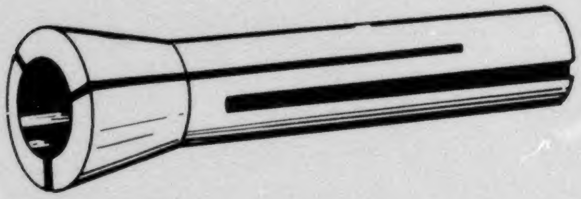




e. ______________________________

f. ______________________________

TEST



g. ______________________________

10. Match attachments to their correct uses. Write the correct numbers in the blanks.

_____a. Indicates precise distance of axis movement, gives positive reading of precision movements, and eliminates need to consider backlash in lead screw

_____b. Enlarges an existing hole to an exact size

_____c. Converts spindle drive so that it is perpendicular to table

_____d. Changes axis of vertical mill spindle so that arbors can be mounted to use cutters other than end mill cutters; also used to hold drills, reamers, and mill cutters parallel to table

_____e. Shapes internal or external surfaces

_____f. Allows very precise rotation of workpiece for repeated cutting operations such as required for gears, splines, or cams

1. Horizontal attachment for vertical mill
2. Boring head
3. Dividing or indexing head
4. Slotting head
5. Digital readout
6. Vertical head for horizontal mill

11. State rules for milling machine safety.

a. Rags — ____

____

____

b. Setup — ____

____

____

c. Cutting tools — _______________________________________

____

____

TEST

d. Feed — ______

e. Cutter rotation — ______

f. Measurements or adjustments — ______

g. Conventional or up-milling — ______

h. Changing parts — ______

i. Arbor nut and drawbar — ______

j. Revolving cutter — ______

k. Machine controls — ______

l. Running machine — ______

TEST

m. Travel levers — ______

n. Positioning workpiece — ______

o. Standing by machine — ______

p. Warning tags or signs — ______

q. Chips — ______

r. Compressed air — ______

s. Work area — ______

t. Heavy objects — ______

TEST

u. Guards — ____________________

____

____

v. Clothing — ____________________

____

____

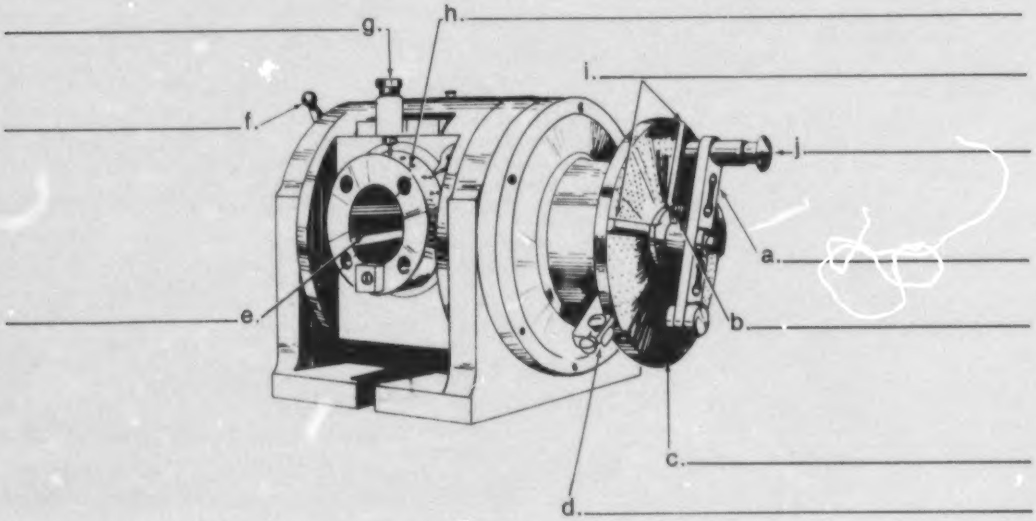
w. Safety glasses with side shields — ____________________

____

____

12. Identify the parts of the indexing or dividing head. Write the correct names in spaces provided.

Spindle nose
Sector arm lockscrew
Direct-indexing holes
Indexing plate
Sector arms
Indexing crank
Indexing plate stop
Indexing crank plunger pin
Spindle lock
Direct-indexing plunger and pin



TEST

13. Match parts of the indexing or dividing head to their correct descriptions or functions. Write the correct numbers in the blanks. Parts and their descriptions or functions continue on the following page.

_____a. Locates exact movement of indexing crank

_____b. Two movable arms that travel set number of holes in hole plate each time indexing crank is turned

_____c. Has a machine taper that centers workholding devices

_____d. Located on the spindle nose; provide for rapid indexing of parts that have divisions in multiples of 15 degrees

_____e. Mechanical lock that prevents spindle from moving

_____f. Turns gearing mechanism of dividing head to rotate workpiece

_____g. Locate and lock in correct indexing hole when direct indexing

_____h. Allows sector arms to be set for a particular number of holes and then locked

_____i. Disc with circular hole patterns used to set workpiece rotation to a specific partial turn

_____j. Locks indexing plate for simple indexing; must be disengaged for direct indexing

1. Spindle nose
2. Sector arms
3. Indexing crank plunger pin
4. Direct-indexing holes
5. Direct-indexing plunger and pin
6. Spindle lock
7. Indexing crank
8. Sector arm lockscrew
9. Indexing plate
10. Indexing plate stop

14. List six operations performed on the dividing or indexing head.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

TEST

15. Calculate direct and simple indexing. Show all work.

    a. Calculate the direct indexing to mill flats on a 2-inch round shaft; the shaft is to have twelve equal sides.

    Answer ________________________________

    b. Calculate the simple indexing required to cut a gear having thirty-six teeth. The dividing head has a 40:1 ratio with three indexing plates.

    Plate 1 — 15-16-17-18-19-20

    Plate 2 — 21-23-27-29-31-33

    Plate 3 — 37-39-41-47-49

    Answer __________ turn(s) __________ hole(s) in __________ hole pattern

c. Calculate the simple indexing required to cut a gear having one-hundred teeth. The dividing head has a 40:1 ratio with a reversible indexing plate.

First side — 24-25-28-30-34-37-38-39-41-42-43

Second side — 46-47-49-51-53-54-57-58-59-62-66

Answer __________ turn(s) __________ hole(s) in __________ hole pattern

16. Select from the following list reasons for using cutting fluids. Write an "X" in the blank before each correct answer.

_____a. To increase tool life

_____b. To help break chips

_____c. To reduce friction by lubrication

_____d. To clean cutting tool

_____e. To wash chips away from workpiece and cutter

_____f. To keep workpiece and tool cool

_____g. To help prevent chips from welding to cutter

_____h. To keep workpiece sharp

17. List the basic groups of cutting fluids.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

TEST

18. Match coolant application methods to their correct descriptions. Write the correct numbers in the blanks.

_____a. Coolant is applied to tool and workpiece manually by brush or oil can

_____b. Jet (10 to 80 psi) applies to cutter and workpiece mist of soluble or synthetic fluid mixed with air

_____c. Pressurized cold air is directed over tool and workpiece

_____d. Coolant under low pressure from one or more nozzles floods tool and workpiece; most common method of applying fluids

1. Flood cooling
2. Mist system
3. Paste or solid application
4. Cold air

19. Identify coolant application methods. Write the correct names in the blanks.

Flood cooling
Mist system
Paste or solid application
Cold air

METHOD	ADVANTAGES	DISADVANTAGES
a. ____________ ____________	Good lubrication Good visibility of cut Excellent coolant distribution Easy to install	Limited cooling power Must be used in well-ventilated area Subject to clogging Requires air source and filter system
b. ____________ ____________	Good visibility of cut Easy to install Good chip control	No lubrication Expensive
c. ____________ ____________	Excellent lubrication and cooling Good chip removal	Expensive to use Messy Costly to install Obscures visibility of cut
d. ____________ ____________	Excellent for hand operations No additional equipment required Inexpensive	Dangerous when using power equipment Poor cooling power Poor chip control

TEST

20. Distinguish among causes of cutter failure and finish problems. Write the correct numbers in the blanks. Some numbers may be used more than once. Blanks may contain more than one answer.

__________a. Excessive revolutions per minute (rpm)

__________b. Inadequate coolant at cut

__________c. Chatter

__________d. Low revolutions per minute (rpm)

__________e. Excessive feed

__________f. Incorrect feed (high or low)

__________g. Loose gibs or play in table

__________h. Bent arbor

__________i. Workpiece not held rigidly

__________j. Cutter ground improperly

__________k. Incorrect cutter

__________l. Cut too deep

__________m. Too many teeth or flutes in cutter

__________n. Chips being recut

__________o. Cutter slipping

__________p. Outboard arbor bushing loose

__________q. Incorrect machine operation

__________r. Workpiece not properly supported

__________s. Incorrect coolant

__________t. Coolant flow direction wrong

__________u. Cutter not properly positioned

__________v. Dull cutter

__________w. Not enough cutting edges

1. Chatter
2. Cutter dulling rapidly
3. Cutting edge chipping
4. Cutter breaking
5. Workpiece material hardening
6. Cutting edge clogging
7. Cutting edge overheating
8. Excessive cratering of carbide

TEST

21. Calculate machine speed and feed rates for the following problems. Show all work. Refer to charts that follow Assignment Sheet #3.

    a. What are the speed and feed rates when using a 1/2-inch diameter four-flute end mill (HSS) to mill a slot 0.150 of an inch deep and 10 inches long in an aluminum alloy bar (SAE 6061T6)?

    Speed = ____________________ rpm Feed = ____________________ ipm

    b. What are the speed and feed rates when using a 7/8-inch drill (HSS) to drill a hole 3 inches deep in a low-carbon steel (SAE 1020) bar?

    Speed = ____________________ rpm Feed = ____________________ ipm

TEST

c. What are the speed and feed rates when using a fourteen-tooth plain mill cutter (HSS) 1/2-wide, 5 inches in diameter to make a roughing cut 0.250 of an inch deep in high-carbon steel (1095)?

Speed = ____________________ rpm Feed = ____________________ ipm

d. What are the speed and feed rates when making a finish cut on soft cast iron using a slab milling cutter to cut a flat surface 3 inches wide, 1/8 inch long with a cutter having six teeth and a 4-inch diameter mounted on a 1 1/4-inch arbor?

Speed = ____________________ rpm Feed = ____________________ ipm

(NOTE: Test questions 22-23 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

22. Complete milling machine safety test.

23. Demonstrate the ability to

    a. Clean and lubricate a horizontal mill.

    b. Clean and lubricate a vertical mill.

INTRODUCTION TO MILLING MACHINES
UNIT I

ANSWERS TO TEST

1.	a.	5	f.	13	k.	4
	b.	11	g.	9	l.	8
	c.	2	h.	6	m.	3
	d.	12	i.	1	n.	7
	e.	14	j.	15	o.	10

2. Answer should include any five of the following
    a. Horizontal mill
    b. Turret mill
    c. Vertical mill
    d. Tracer or duplicating mill
    e. Bed-type manufacturing mill
    f. Precision jig bore
    g. Computerized mill

3.	a.	4	f.	13	k.	2
	b.	7	g.	8	l.	10
	c.	5	h.	11	m.	6
	d.	12	i.	3	n.	14
	e.	1	j.	9		

4. **Column**

a.	1	f.	2
b.	6	g.	9
c.	5	h.	7
d.	4	i.	8
e.	3		

ANSWERS TO TEST

Knee

a.	2	f.	1
b.	6	g.	3
c.	7	h.	4
d.	5	i.	8
e.	9		

Saddle

a.	4	c.	2
b.	1	d.	3

Table

a.	2	d.	5
b.	1	e.	4
c.	3		

5.

a.	14	g.	1	m.	11
b.	5	h.	9	n.	13
c.	4	i.	2		
d.	6	j.	8		
e.	3	k.	7		
f.	10	l.	12		

ANSWERS TO TEST

6. **Milling head**

a.	6	f.	9	k.	3
b.	13	g.	2	l.	5
c.	4	h.	7	m.	14
d.	1	i.	8	n.	10
e.	11	j.	12	o.	15

Ram and swivel

a.	8	e.	6
b.	1	f.	2
c.	7	g.	5
d.	4	h.	3

Table

a.	3	d.	4
b.	2	e.	1
c.	5		

Saddle and knee

a.	6	d.	5
b.	1	e.	4
c.	2	f.	3

7. a. Air vise
   b. V-block and clamp
   c. Hold-down clamp
   d. Fixture
   e. Precision angle table (adjustable)
   f. Rotary table
   g. Vise with swivel base
   h. Heavy-duty angle vise
   i. Angle plate
   j. Indexing (dividing) head and attachments

ANSWERS TO TEST

8. a. Single-end, two-flute helical end mill
   b. Woodruff keyseat cutter
   c. Combination drill and countersink (center drill)
   d. Roughing end mill
   e. Reamer
   f. Insert-type end mill
   g. Staggered-tooth mill cutter
   h. Involute gear cutter
   i. Ball-nose end mill
   j. Countersink
   k. Concave mill cutter
   l. Corner-rounding mill cutter (radius cutter)
   m. Counterbore with pilot
   n. Helical mill cutter
   o. Shell mill cutter
   p. Corner-rounding end mill (radius-cutting end mill)
   q. Dovetail-cutting end mill
   r. Double-end, two-flute helical end mill
   s. Four-flute end mill
   t. Straight-shank drill
   u. Plain metal-slitting saw
   v. Double-angle mill cutter
   w. Side mill cutter
   x. Convex mill cutter
   y. Single-angle mill cutter
   z. Plain mill cutter

ANSWERS TO TEST

9. a. Shell mill arbor
   b. Style C arbor
   c. Taper adapter
   d. End mill holder
   e. Style A arbor
   f. Style B arbor
   g. Collet

10. a. 5
    b. 2
    c. 6
    d. 1
    e. 4
    f. 3

11. a. Rags — Use when handling cutters to avoid injury to hands; however, do not use around revolving cutters

    b. Setup — Make sure that setup holds workpiece rigidly and that workpiece is tightly clamped to prevent slippage under cutter force, which may result in damage to cutter or workpiece or in injury to personnel

    c. Cutting tools — Make sure that cutting tools are always keyed to arbor or held securely in holder to prevent slippage

    d. Feed — Adjust so that workpiece moves at proper feed to prevent damage to cutter and to produce desired finish

    e. Cutter rotation — Adjust so that cutter rotates at proper surface feet per minute to prevent damage to cutter

    f. Measurements or adjustments — To eliminate the possibility of an accident, stop cutter rotation before taking measurements or making adjustments

    g. Conventional or up-milling — Feed work into cutter or against rotation of cutter when making heavy cuts

    h. Changing parts — To avoid possible injury to hands or arms, move workpiece as far away from cutter as possible

    i. Arbor nut and drawbar — Never attempt to tighten or loosen arbor nut or drawbar with machine power

    j. Revolving cutter — Never reach over or touch revolving cutter with hands

ANSWERS TO TEST

k. Machine controls — Know location and use of all machine controls

l. Running machine — Always stay within reach of stop switch while machine is running; never leave a running machine unattended

m. Travel levers — Always check machine travel levers before using machine

n. Positioning workpiece — Always use handcranks when positioning workpiece near cutter; never use power to set up

o. Standing by machine — Never lean on machine

p. Warning tags or signs — Never use a machine that has a sign or warning tag indicating a dangerous condition or indicating that machine needs repair

q. Chips — Never handle chips with bare hands because they can cut or burn

r. Compressed air — Take extreme caution to avoid forcing chips between work surfaces and to prevent injury from flying chips

s. Work area — To prevent the possibility of slipping or stumbling, keep area around machine clean and free of oil, chips, and other obstructions

t. Heavy objects — Use a hoist or ask for help when lifting

u. Guards — Never operate a machine with guards removed

v. Clothing — Wear close-fitting clothing, with shirt tucked in and sleeves buttoned or rolled above elbows

w. Safety glasses with side shields — Wear at all times

12. a. Indexing crank
    b. Sector arm lockscrew
    c. Indexing plate
    d. Indexing plate stop
    e. Spindle nose
    f. Spindle lock
    g. Direct-indexing plunger and pin
    h. Direct-indexing holes
    i. Sector arms
    j. Indexing crank plunger pin

ANSWERS TO TEST

13.

a.	3	f.	7
b.	2	g.	5
c.	1	h.	8
d.	4	i.	9
e.	6	j.	10

14. Answer should include any six of the following

a. Cutting splines

b. Cutting gears

c. Cutting helixes

d. Cutting cams

e. Machining straight-tooth clutches

f. Machining flats at designated angles

g. Drilling holes at designated angles

h. Ruling or graduating parts

15. a. 2 holes

b. 1 turn 2 holes in 18-hole pattern

c. 0 turns 12 holes in 30-hole pattern

16. c, e, f, g

17. a. Cutting oils

b. Emulsifiable oils

c. Chemical and synthetic emulsions

d. Special cutting fluids

ANSWERS TO TEST

18. a. 3
    b. 2
    c. 4
    d. 1

19. a. Mist system
    b. Cold air
    c. Flood cooling
    d. Paste or solid application

20. a. 1, 2, 5, 6, 7, 8
    b. 2, 5, 6, 7
    c. 2, 3
    d. 3
    e. 1, 3, 4, 5, 6, 8
    f. 2
    g. 3, 4
    h. 3
    i. 1, 4
    j. 2, 3, 7, 8
    k. 2, 6, 7, 8
    l. 3, 4, 7
    m. 2, 6
    n. 3
    o. 1, 3, 4
    p. 3
    q. 4
    r. 1
    s. 2, 5, 6, 7
    t. 6
    u. 1
    v. 1, 4, 5, 7
    w. 3

21. a. 2,000 rpm, 16.0 ipm
    b. 411.4 rpm, 4.9 ipm
    c. 64.0 rpm, 5.4 ipm
    d. 225 rpm, 13.5 ipm

22. Evaluated to the satisfaction of the instructor

23. Performance skills evaluated to the satisfaction of the instructor

HORIZONTAL MILLING MACHINES
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to set up and operate a horizontal mill. This knowledge will be shown by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with horizontal milling machines.
2. Name types of horizontal milling operations.
3. List horizontal milling operations required to make parts.
4. Demonstrate the ability to
    a. Mount a style "A" or "B" arbor and adjust arbor support bushing.
    b. Use machine controls properly.
    c. Mount cutter to arbor.
    d. Mount and align swivel-base vise.
    e. Align work mounted to table.
    f. Align angle plate at right angle to column.
    g. Mill square a workpiece mounted in vise.
    h. Perform face milling operation using style "C" arbor.
    i. Mill a keyway with staggered-tooth mill cutter.
    j. Perform a straddle milling operation.
    k. Mill an angle with single-angle mill cutter.
    l. Mill to blueprint specifications using machine controls.

HORIZONTAL MILLING MACHINES
UNIT II

SUGGESTED ACTIVITIES

I. Suggested Activities

   A. Order materials to supplement unit.

      1. Operator's manuals for the machines the students will be using.

      2. If possible, acquire a fixture and material from a local industry to set up for a production run in your shop.

   B. Provide students with objective sheet.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information and assignment sheets.

   F. Discuss and demonstrate procedures outlined in job sheets.

   G. Provide alternate jobs or change job sheets to fit equipment in your shop if necessary.

   H. Give test.

   I. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Assignment Sheet #1—List Horizontal Milling Operations Required to Make Parts

   E. Answers to assignment sheet

   F. Job sheets

      1. Job Sheet #1—Mount a Style "A" or "B" Arbor and Adjust Arbor Support Bushing

      2. Job Sheet #2—Use Machine Controls Properly

      3. Job Sheet #3—Mount Cutter to Arbor

      4. Job Sheet #4—Mount and Align Swivel-Base Vise

SUGGESTED ACTIVITIES

5. Job Sheet #5—Align Work Mounted to Table
6. Job Sheet #6—Align Angle Plate at Right Angle to Column
7. Job Sheet #7—Mill Square a Workpiece Mounted in Vise
8. Job Sheet #8—Perform Face Milling Operation Using Style "C" Arbor
9. Job Sheet #9—Mill a Keyway with Staggered-Tooth Mill Cutter
10. Job Sheet #10—Perform a Straddle Milling Operation
11. Job Sheet #11—Mill an Angle with Single-Angle Mill Cutter
12. Job Sheet #12—Mill to Blueprint Specifications Using Machine Controls

G. Test

H. Answers to test

III. Unit references

A. Kibbe, Richard R., et al. *Machine Tools and Machining Practices: Volume Two.* New York: John Wiley and Sons, Inc., 1979.

B. Krar, S.F., J.W. Oswald, and J.E. St. Amand. *Technology of Machine Tools.* Toronto: McGraw-Hill of Canada, 1969.

C. Olivio, Thomas C. *Fundamentals of Machine Technology.* Belmont, California: Wadsworth Publishing Company, Inc., 1981.

HORIZONTAL MILLING MACHINES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Set up—To prepare the machine prior to performing a particular operation

(NOTE: Setting up may involve mounting cutters and work-holding devices; setting speeds, feeds, and stops; and aligning workpiece and work-holding devices.)

B. Align—To set correct relative position between cutter axis and workpiece

C. Axis—Center line of cutter rotation

D. Indicate—To align by using dial indicator

E. Square—To align at 90-degree angle

F. Seat—To set a workpiece solidly in work-holding device

G. Spindle rotation—Direction spindle revolves as viewed from front of machine; referred to as right-hand (clockwise) or left-hand (counterclockwise)

H. Parallels—Accurately machined bars with adjacent sides square to each other and opposite sides parallel; made in matched sets; used to support workpiece when machining or setting up

I. Shims—Thin pieces of metal, usually steel, used to level or align workpiece or work-holding device when setting up

J. Indexing—Process of dividing circular or straight part into exact division

K. T-slot—T-shaped groove machined into tables and attachments to allow the use of bolts and nuts when mounting work-holding devices or accessories

L. Helix—Curved path that advances at a uniform rate along a cylinder

EXAMPLE: The spiral cutting edge of a drill or mill cutter is a helix.

M. Fly-cutter—Special holder that may hold from one to six tool blanks

N. Cutter size—Method of describing the diameter, width, and hole or shank size of a mill cutter

EXAMPLES: 6" × 3/4" × 1 1/2" staggered-tooth mill cutter
1/2" × 2 1/2" × 1/2" end mill cutter

INFORMATION SHEET

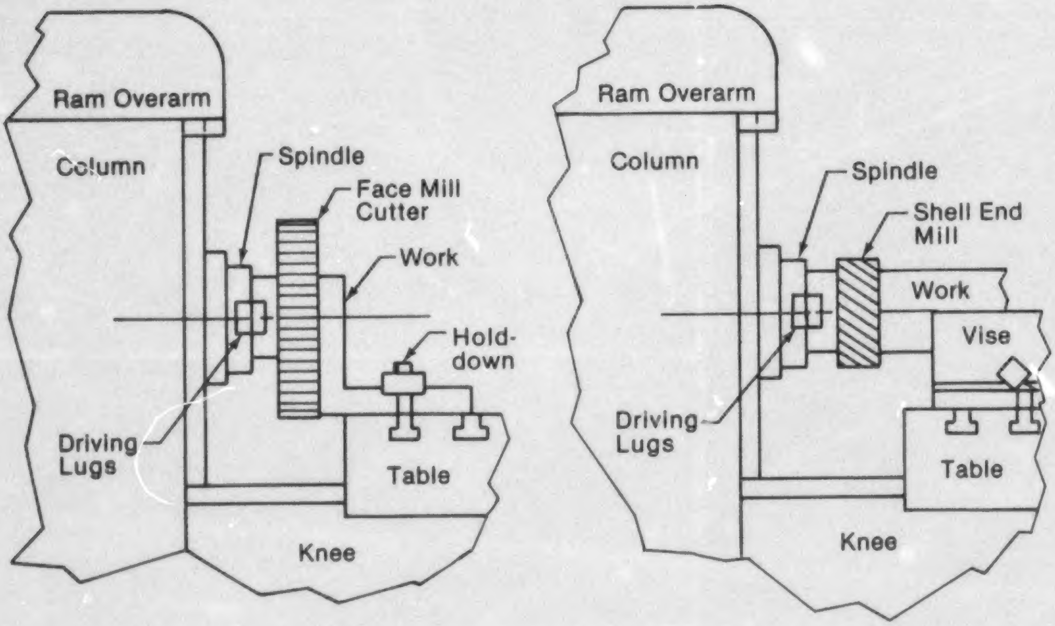
II. Types of horizontal milling operations (Assignment Sheet #1)

A. Face milling—Machining a surface that is parallel to face of cutter

(NOTE: Large areas are machined with face mill cutters; small areas are machined with shell end-mill cutters. See Figure 1.)

EXAMPLE:

FIGURE 1


Ram Overarm
Column
Spindle
Face Mill Cutter
Work
Hold-down
Driving Lugs
Table
Knee
Ram Overarm
Column
Spindle
Shell End Mill
Work
Vise
Driving Lugs
Table
Knee

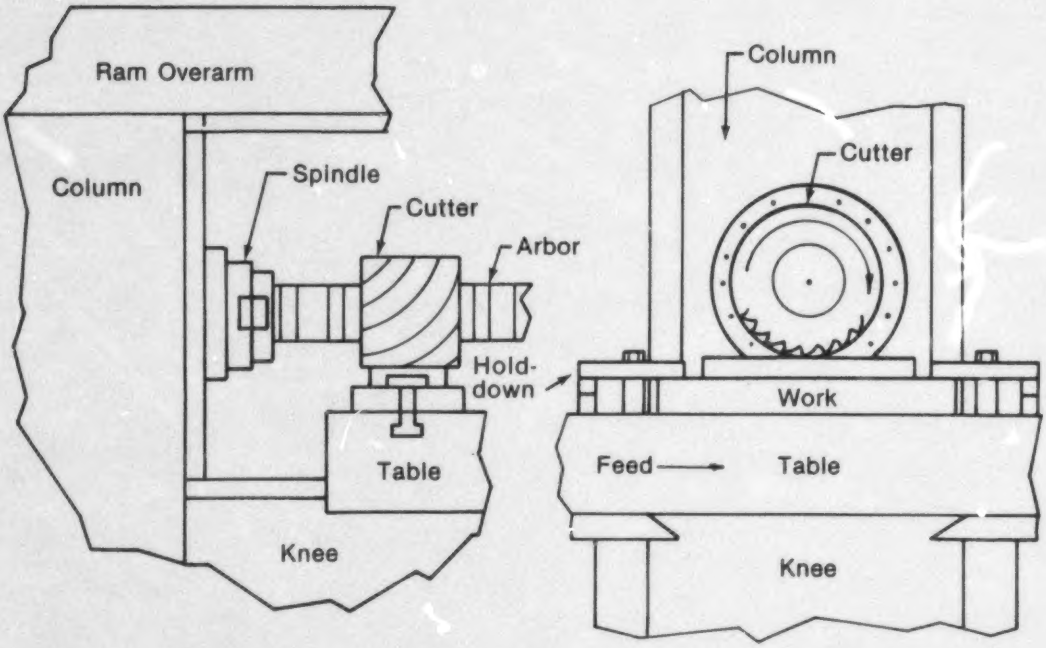
INFORMATION SHEET

B. Slab milling (plain milling)—Milling a flat surface using the peripheral teeth of an arbor-mounted mill cutter

(NOTE: Cutters used in slab milling are usually the same width as the workpiece. See Figure 2.)

EXAMPLE:

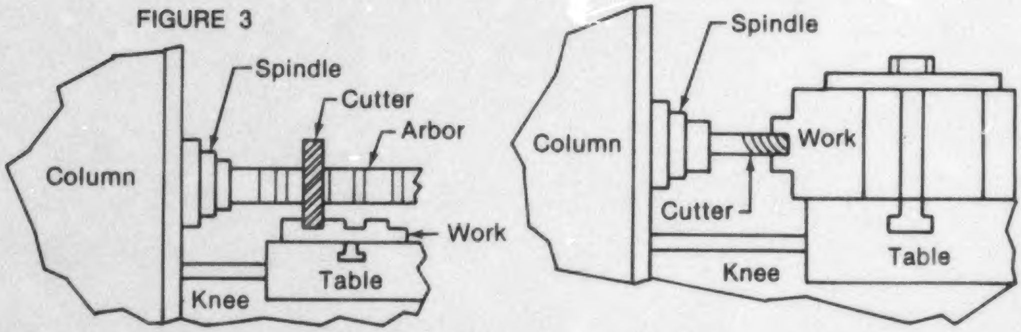
FIGURE 2


Ram Overarm
Column
Spindle
Cutter
Arbor
Hold-down
Table
Knee
Column
Cutter
Work
Feed →
Table
Knee

C. Slotting (grooving)—Milling a recess with an arbor-mounted or spindle-mounted cutter (Figure 3)

EXAMPLE:

FIGURE 3

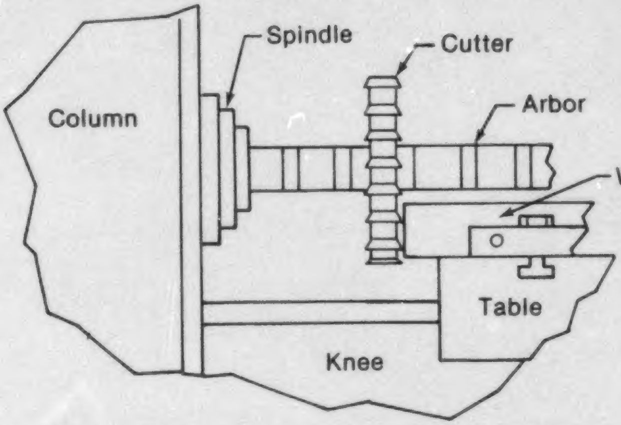

Spindle
Cutter
Arbor
Column
Work
Table
Knee
Spindle
Column
Work
Cutter
Table
Knee

INFORMATION SHEET

D. Side milling—Machining the end of workpiece with a cutter having side-cutting teeth (Figure 4)

EXAMPLE:

FIGURE 4

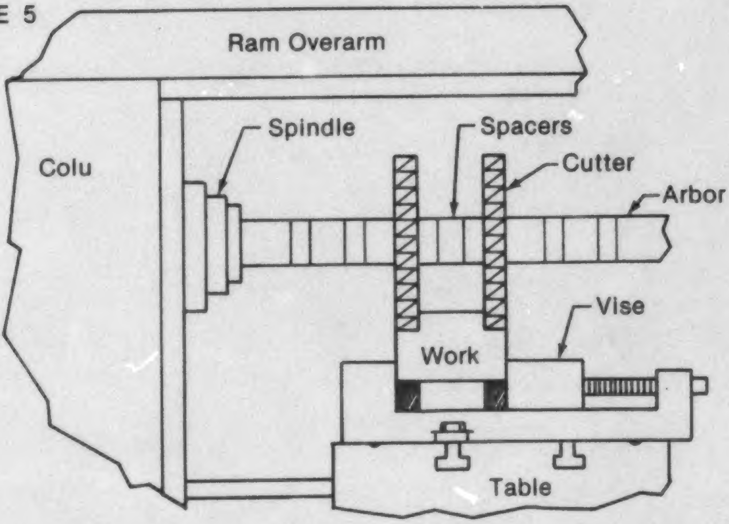

Spindle
Cutter
Column
Arbor
Work
Table
Knee

E. Straddle milling—Using two arbor-mounted cutters to make two parallel cuts in one operation (Figure 5)

(NOTE: Straddle milling is similar to side milling.)

EXAMPLE:

FIGURE 5


Ram Overarm
Spindle
Spacers
Cutter
Colu
Arbor
Vise
Work
Table

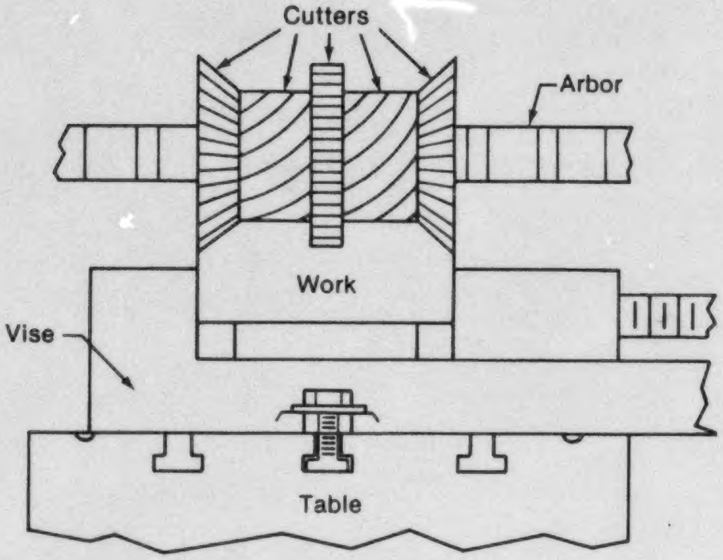
INFORMATION SHEET

F. Gang milling—Using a number of cutters to cut several surfaces in one operation (Figure 6)

(NOTE: The cutters used in gang milling may vary greatly in size and shape depending on the pattern to be milled.)

EXAMPLE:

FIGURE 6

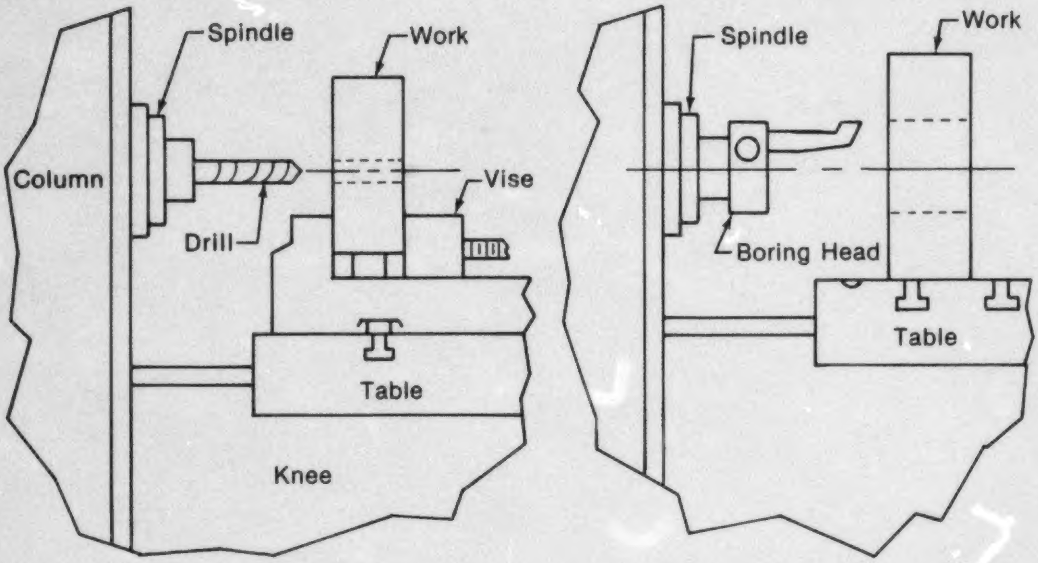

Cutters
Arbor
Work
Vise
Table

INFORMATION SHEET

G. Drilling (boring)—Producing or enlarging a hole with a bit or boring tool mounted in spindle of horizontal milling machine (Figure 7)

EXAMPLE:

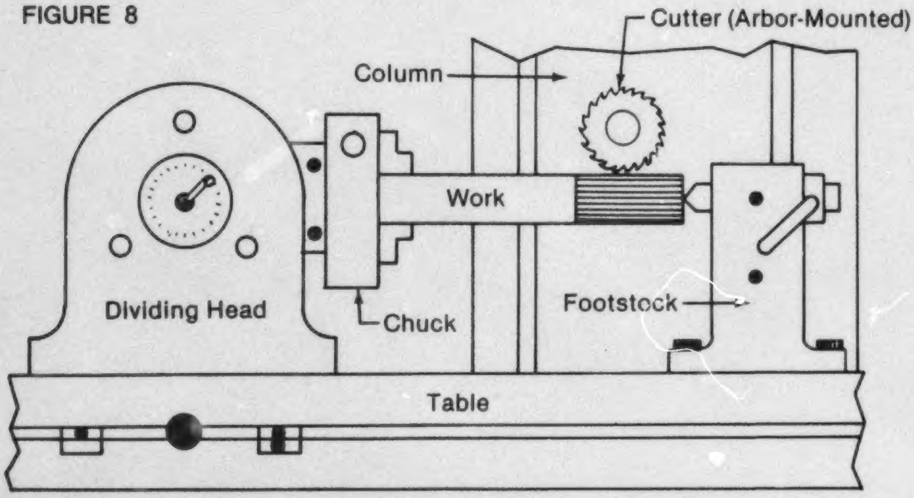
FIGURE 7


Spindle
Work
Column
Vise
Drill
Table
Knee
Spindle
Work
Boring Head
Table

H. Indexing—Dividing a workpiece into equal spaces, angles, or divisions about an axis, using a dividing head to rotate workpiece (Figure 8)

EXAMPLE: Gears, splines, and hexagons require indexing.

FIGURE 8


Cutter (Arbor-Mounted)
Column
Work
Dividing Head
Chuck
Footstock
Table

HORIZONTAL MILLING MACHINES
UNIT II

ASSIGNMENT SHEET #1 — LIST HORIZONTAL MILLING OPERATIONS REQUIRED TO MAKE PARTS

NAME ______________________________ SCORE ____________

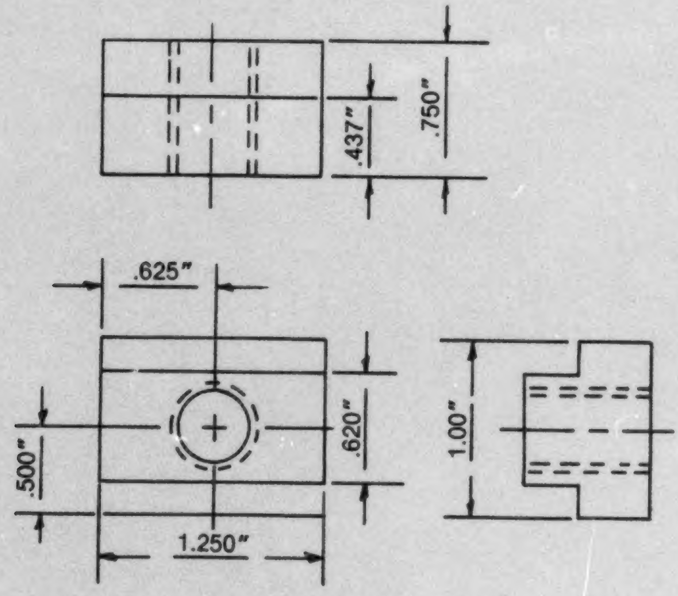
Increased productivity results from prior planning and careful determination of the operations required to make a part or parts in the least amount of time.

List the milling operations performed on the horizontal mill to make the following parts.

A. Make T-nuts from bar steel 1" × 3/4" × 7 1/2"

(NOTE: Disregard the drilling operation.)

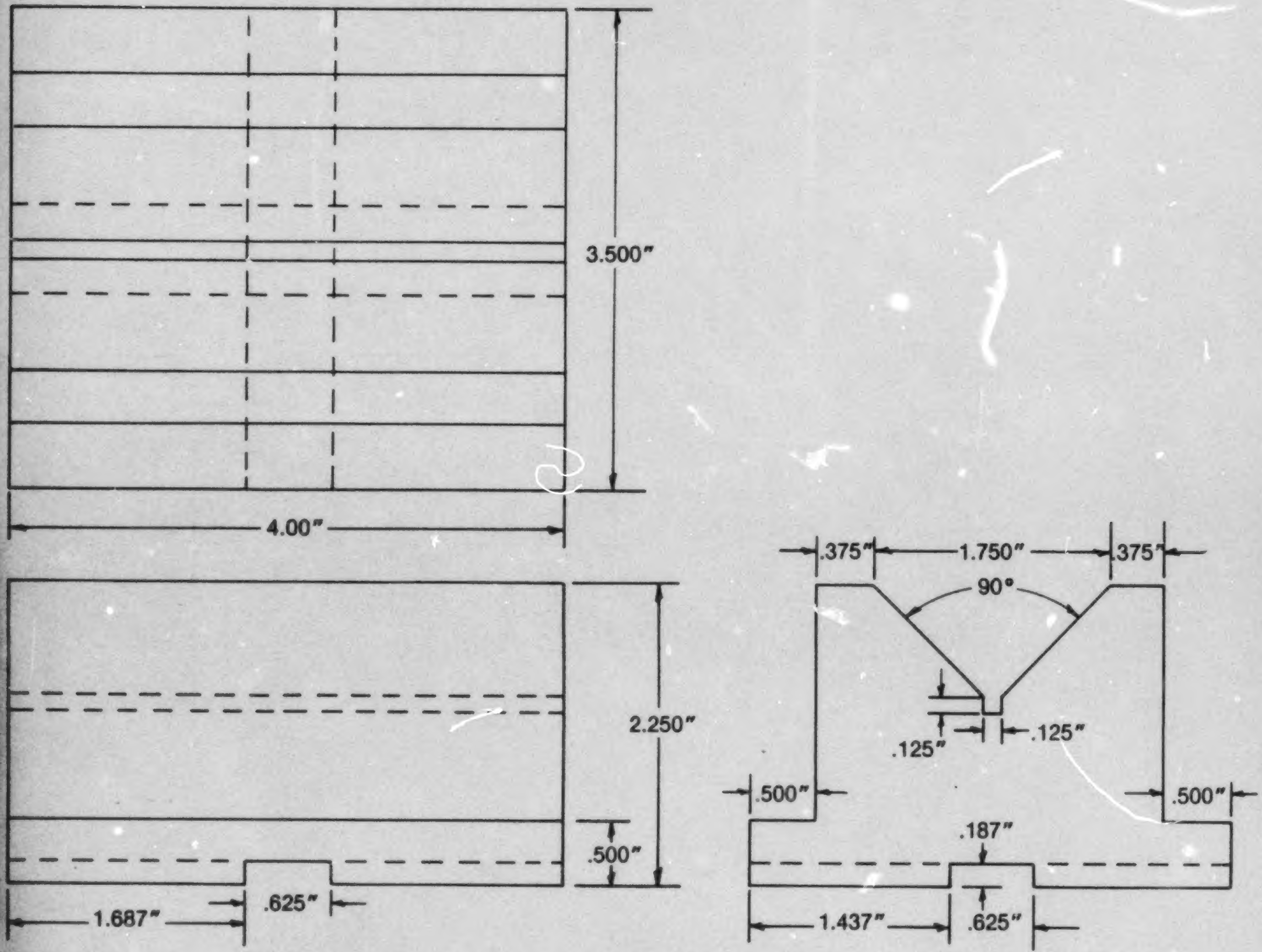
1. ______________________________
2. ______________________________



B. Make V-block shown on next page.

1. ______________ 4. ______________
2. ______________ 5. ______________
3. ______________ 6. ______________

ASSIGNMENT SHEET #1


3.500"
4.00"
.375"
1.750"
.375"
90°
.125"
.125"
2.250"
.500"
.500"
.500"
.187"
.500"
1.687"
.625"
1.437"
.625"

HORIZONTAL MILLING MACHINES
UNIT II

ANSWERS TO ASSIGNMENT SHEET

A. 1. Straddle mill

2. Face or side mill to length

B. 1. Slab mill square

2. Straddle mill

3. Mill angle

4. Mill 1/8-inch slot (splitting saw)

5. Mill 5/8-inch slot (plain mill)

6. Face or side mill to length

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #1 — MOUNT A STYLE "A" OR "B" ARBOR AND ADJUST ARBOR SUPPORT BUSHING

I. Equipment and materials

- A. Horizontal milling machine
- B. Style "A" or "B" arbor
- C. Arbor support
- D. Clean rag
- E. Lubricating oil
- F. Adjustable wrench (18 inch) or open-end wrench to fit drawbar locknut
- G. Spanner or special wrench for adjusting arbor support bushing

II. Procedure

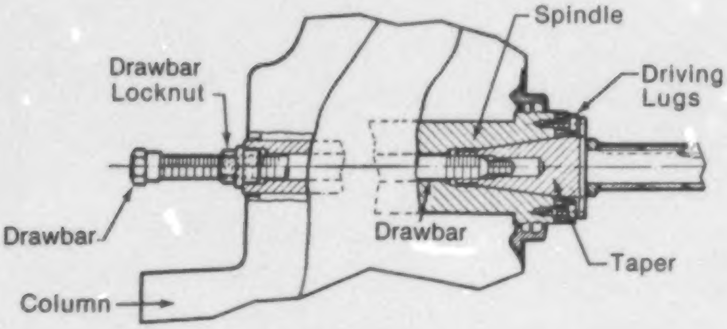
- A. Prepare to mount arbor
  1. Clean mill spindle with clean rag to remove any foreign matter
  2. Clean arbor machine taper and apply a thin coat of light oil to taper
  3. Insert arbor taper into spindle taper so that machined slots on arbor line up with driving lugs on spindle
  4. Turn drawbar with one hand in a clockwise direction while holding arbor securely in spindle with other hand
  5. Continue turning for five complete revolutions

     (NOTE: The drawbar locknut may need to be loosened.)
  6. Check to see that milling machine is set to low speed range

JOB SHEET #1

7. Turn drawbar locknut until flange of drawbar locknut is securely against spindle; tighten with wrench (Figure 9)

FIGURE 9

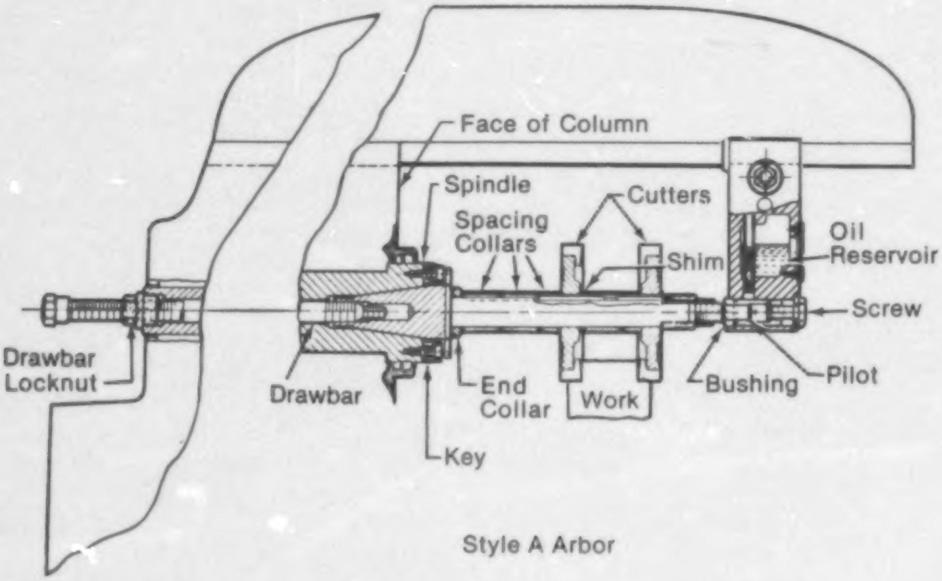

Spindle
Drawbar Locknut
Driving Lugs
Drawbar
Drawbar
Taper
Column

Adapted with permission of Cincinnati Milacron, Inc.

B. Mount style "A" arbor

1. Lubricate arbor pilot (Figure 10)

FIGURE 10


Face of Column
Spindle
Cutters
Spacing Collars
Oil Reservoir
Shim
Screw
Drawbar Locknut
Drawbar
End Collar
Work
Bushing
Pilot
Key

Style A Arbor

Adapted with permission of Cincinnati Milacron, Inc.

JOB SHEET #1

2. Mount arbor support on dovetail of overarm and slide it onto pilot to support free end of arbor

3. Tighten adjusting screw until snug, and then back off one revolution to allow for expansion

4. Tighten arbor support nut to lock arbor in place

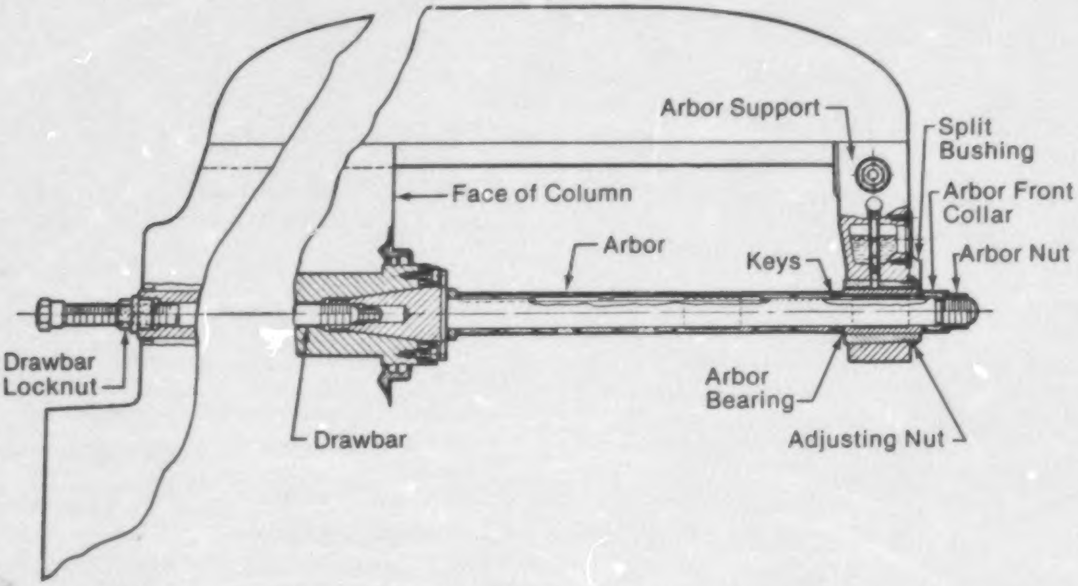
C. Mount style "B" arbor

1. Mount arbor support on overarm

2. Lubricate arbor bearing

3. Slide arbor support to center bearing in split bushing (Figure 11)

FIGURE 11

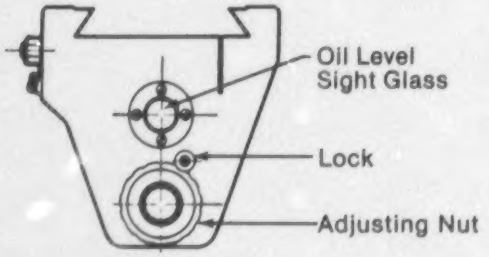

Arbor Support
Split Bushing
Face of Column
Arbor Front Collar
Arbor
Keys
Arbor Nut
Drawbar Locknut
Arbor Bearing
Drawbar
Adjusting Nut

Adapted with permission of Cincinnati Milacron, Inc.

JOB SHEET #1

4. Loosen lock on adjusting nut (Figure 12)

FIGURE 12



Adapted with permission of Cincinnati Milacron, Inc.

5. Insert spanner wrench in holes of adjusting nut

6. Tighten adjusting nut until snug, and then back off one revolution

7. Tighten adjusting nut lock

   (CAUTION: If the arbor bearing begins to squeal, or if the arbor support is hot to the touch, stop machine and loosen adjusting nut by tapping it gently.)

D. Remove arbor

1. Loosen arbor support nut and remove arbor support

   (CAUTION: When removing an arbor that has a mounted cutter, the arbor nut must be loosened before removing the arbor support to prevent the arbor from springing.)

2. Loosen drawbar locknut about one revolution

3. Tap end of drawbar with lead mallet to break the taper

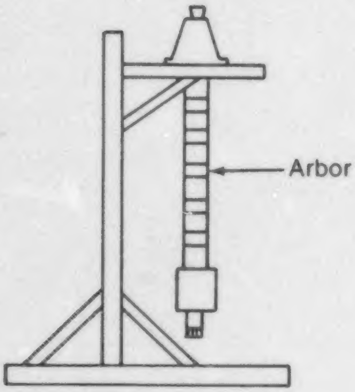
4. Hold arbor in spindle with one hand, and turn drawbar counterclockwise until it is free

JOB SHEET #1

5. Remove arbor and store properly

   (CAUTION: Arbors should always be stored in vertical plane to prevent warpage. See Figure 13.)

FIGURE 13



6. Put away tools and clean work area

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #2 — USE MACHINE CONTROLS PROPERLY

I. Equipment and materials

- A. Horizontal milling machine
- B. Operator's manual
- C. Lubricating oil
- D. Clean rag

II. Procedure

- A. Practice hand operations
  1. Locate table locks for longitudinal, traversal, and elevating movements; put all locks in unlocked position
  2. Move table longitudinally
     - a. Turn left longitudinal table handcrank four revolutions clockwise, then two revolutions counterclockwise

       (NOTE: The slack movement in the handcrank is known as *backlash*.)
     - b. Turn handcrank one revolution clockwise; zero graduated collar, and then turn handcrank clockwise until table has moved 2.562 inches
     - c. Crank table left past zero reading to 0.050 inch; then return table to zero reading

       (NOTE: Moving the table 0.050 inch past zero reading removes the error due to backlash in the lead screw.)
  3. Move table traversally
     - a. Turn traversal handcrank clockwise one revolution; zero graduated collar
     - b. Turn handcrank clockwise to move table 1.125 inches
     - c. Return table to zero reading, removing backlash by moving past zero reading first

4. Move table vertically

    a. Turn elevating handcrank one revolution clockwise; zero graduated collar

    b. Turn handcrank clockwise to raise table 1.437 inches

    c. Lower table to zero reading, removing backlash by lowering past zero reading first

    (NOTE: Because the weight of the table rests on the lead screw, there is very little backlash in the vertical movements of the table.)

B. Practice power operations

(NOTE: Never use power feeds to set up work.)

1. Check to see that all three feed-engaging levers are in neutral position and that all locks are off

2. Check oil levels

3. Check to see that clutch is disengaged; start motor

4. Set speed

    (NOTE: With machines that have variable speed pulleys, the speed can be set while the feed is on and operating; however, for machines with transmission or speed-range levers, the feed must be off to set speeds.)

    a. Start spindle if required

    (NOTE: Speeds on machines with transmissions or speed-range levers can only be adjusted when spindle is *not* turning; however, to prevent damage to the drive belt, speeds on machines with variable speed pulleys must only be adjusted when spindle *is* turning.)

    b. Put machine in high speed range

    c. Set speed indicator to 300 revolutions per minute (rpm)

    d. Start spindle if required

    e. Allow spindle to reach operating speed and observe operation

JOB SHEET #2

  - f. Stop spindle for speed adjustments if required
  - g. Put machine in low speed range
  - h. Set speed indicator to 50 rpm
  - i. Start spindle if required
  - j. Allow spindle to reach operating speed and observe operation
  - k. Stop spindle
  - l. Turn spindle-reversing lever
  - m. Start spindle and note rotation of spindle

5. Set feed at 4½ inches per minute (rpm)
6. Move longitudinal-feed lever to right, and allow table to travel 3 inches; then move lever to left, and allow table to travel 3 inches
7. Disengage longitudinal-feed lever
8. Set table stops 4 inches each side of engagement lever; engage power feed and allow table to move right and left until table movement is stopped by table stops
9. Move table stops to extreme right and left positions
10. Engage cross feed to feed table in and out; return cross-feed lever to neutral position
11. Engage vertical feed to raise and lower table and knee; return vertical feed lever to neutral position
12. Engage longitudinal feed to right
13. Engage rapid traverse; observe table speed and movement past stops

    (CAUTION: Use care when engaging the rapid traverse because it affects each of the three power feeds that are engaged.)

JOB SHEET #2

C. Identify coolant controls

  1. Locate coolant pump on/off switch
  2. Locate valve that regulates coolant flow

     (NOTE: Usually the coolant does not start until the spindle begins to rotate.)

D. Wipe machine with clean rag; apply a thin coat of oil to all unpainted metal surfaces

E. Put away tools and clean work area

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #3 — MOUNT CUTTER TO ARBOR

I. Equipment and materials

A. Horizontal milling machine with arbor support

B. Style "A" or "B" arbor, 18 inches to 24 inches long with spacers, keys, and bushing

C. Rag

D. Lubricating oil

E. Wrench for drawbar and arbor nut

F. Wrenches for arbor support, overarm, and arbor support bushing

G. Staggered-tooth or plain mill cutter, 5 inches or 6 inches with hole size to fit arbor

II. Procedure

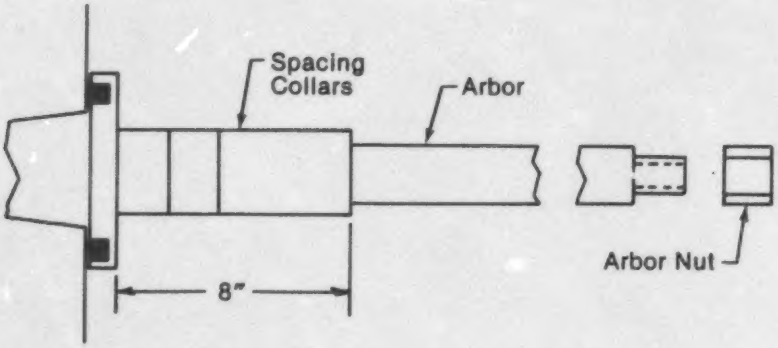
A. Mount arbor on mill

B. Use hands to remove arbor nut

C. Remove bearings and spacers until about 8 inches of spacers remain on arbor (Figure 14)

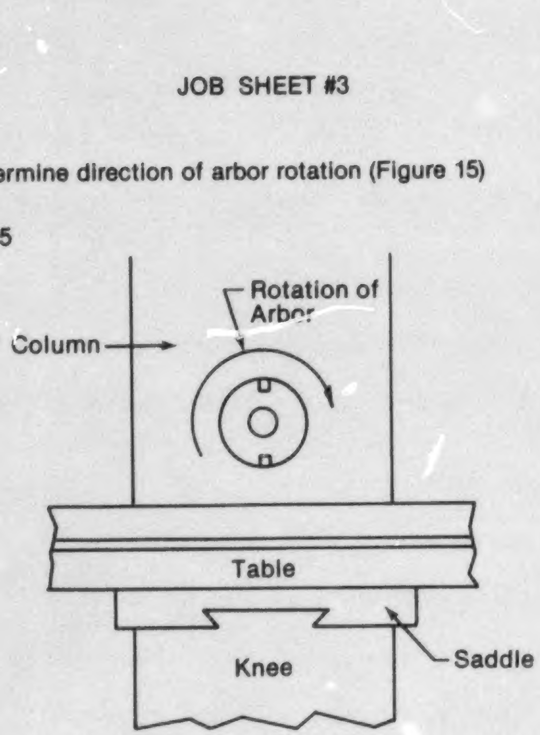
(NOTE: The spacing of the cutter on the arbor varies with the operation to be performed.)

FIGURE 14



D. Determine direction of arbor rotation (Figure 15)

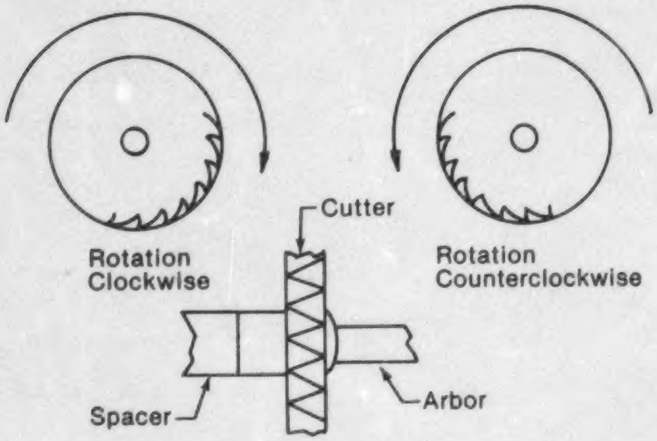
FIGURE 15


Rotation of Arbor
Column
Table
Knee
Saddle

E. Use rag to pick up cutter

F. Turn cutter for proper direction of rotation; slide cutter onto arbor until it rests against spacer (Figure 16)

FIGURE 16


Rotation Clockwise
Cutter
Rotation Counterclockwise
Spacer
Arbor

G. Key cutter to arbor with correctly sized key stock

H. Slide spacing collars onto arbor so that spacing equals 6 inches

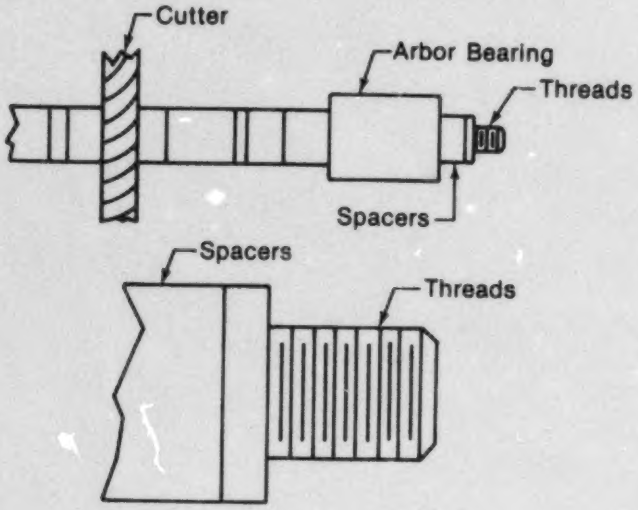
JOB SHEET #3

I. Install bushing; key to arbor

J. Add spacers over remaining unthreaded portion of arbor (Figure 17)

(NOTE: The arbor bearing is larger in diameter than the spacing collars.)

FIGURE 17



K. Finger-tighten arbor nut until it contacts spacers

(CAUTION: Never tighten or loosen arbor nut unless arbor support is in place; otherwise, you will damage arbor.)

L. Slide overarm arbor support until it is centered on arbor bearing

M. Secure arbor support to overarm

N. Adjust arbor support bushing with wrench

O. Put away tools and clean work area

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #4 — MOUNT AND ALIGN SWIVEL-BASE VISE

I. Equipment and materials

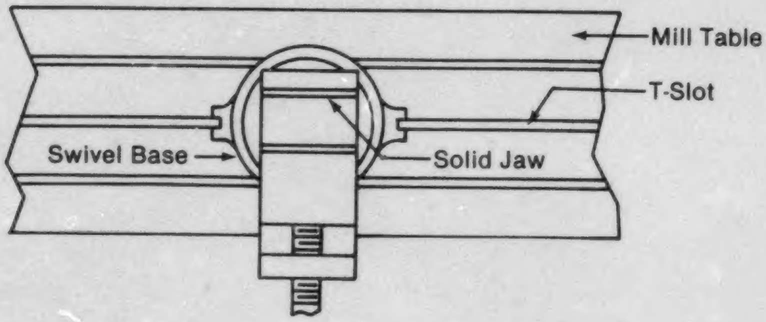
- A. Horizontal milling machine with arbor
- B. Dial indicator with attachments
- C. Vise with swivel base
- D. T-bolts and flange nuts
- E. Clean rag
- F. Wrenches
- G. Soft-faced mallet

II. Procedure

- A. Clean mill table
- B. Place vise on bench with bottom up
- C. Clean bottom of vise with rag
- D. Mount arbor in spindle with arbor support in place
- E. Place vise on table with solid jaw parallel to T-slots (Figure 18)

  (NOTE: If the vise has alignment keys, they should be placed in the T-slots of the mill table.)

FIGURE 18



JOB SHEET #4

F. Place T-bolts in T-slots, and slide bolts into swivel base slots

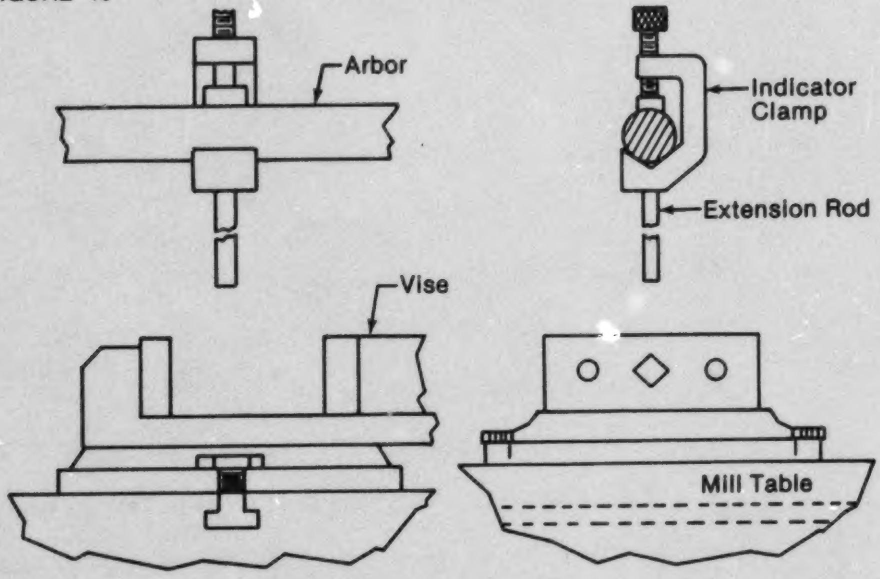
(NOTE: Some vises use securing holes instead of slots. For this type of design, place the T-bolts in the slots and position them before mounting the vise.)

G. Screw on flange nuts to secure vise to table

H. Loosen nuts that secure vise to swivel base; then retighten until just snug

I. Mount indicator extension rod to indicator clamp and secure to arbor so that rod is pointing down, near solid jaw (Figure 19)

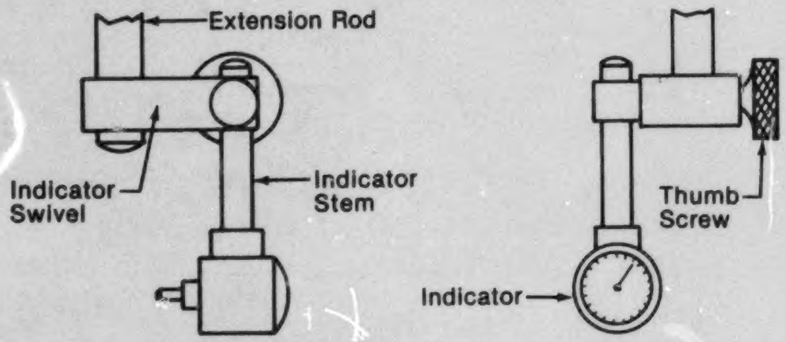
FIGURE 19


Arbor
Indicator Clamp
Extension Rod
Vise
Mill Table

J. Mount indicator swivel to extension rod

K. Insert indicator stem in swivel; tighten thumb screw (Figure 20)

FIGURE 20

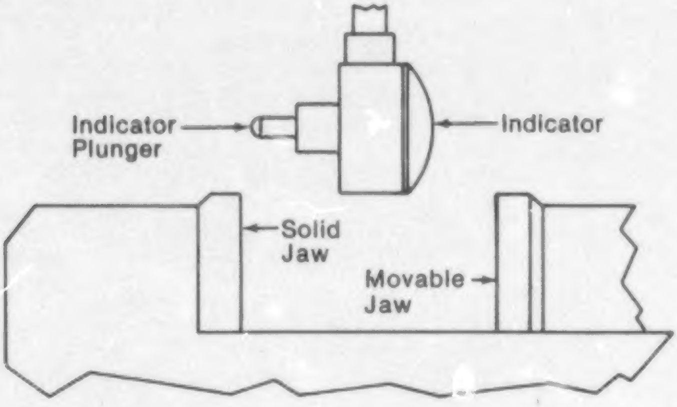

Extension Rod
Indicator Swivel
Indicator Stem
Thumb Screw
Indicator

JOB SHEET #4

L. Center indicator over vise between solid jaw and movable jaw, with plunger of indicator pointing toward solid jaw (Figure 21)

(NOTE: The solid or fixed jaw is the only jaw that is ever used tc accurately align the vise.)

FIGURE 21

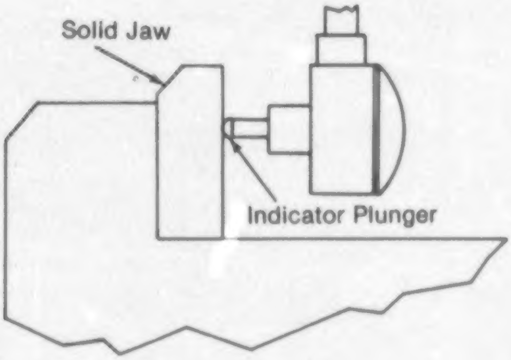

Indicator Plunger
Indicator
Solid Jaw
Movable Jaw

M. Crank up table so that indicator is between vise jaws

N. Move table cross feed so that solid jaw makes contact with indicator plunger (Figure 22)

(CAUTION: Do not use power feeds to move vise around indicator.)

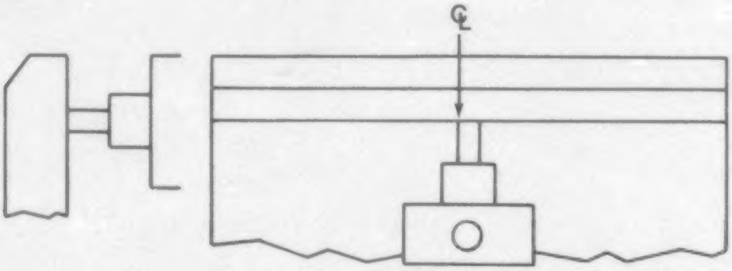
FIGURE 22


Solid Jaw
Indicator Plunger

JOB SHEET #4

O. Center indicator plunger on length of jaw by turning longitudinal-feed handwheel (Figure 23)

FIGURE 23



P. Continue turning handwheel until indicator reads 0.015 inch

Q. Zero indicator

R. Use longitudinal-feed handwheel to move table so that indicator is about 1/4 inch from end of solid jaw that produces a positive reading on indicator

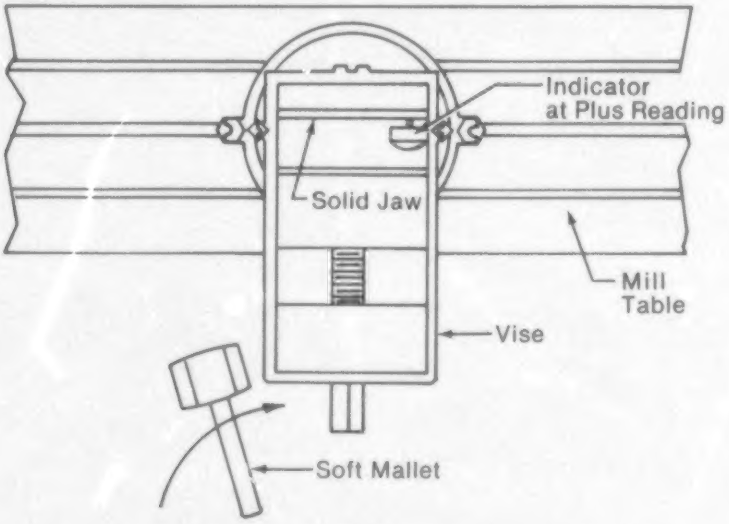
(CAUTION: Do not allow indicator to go off the end of solid jaw.)

S. Note indicator reading

T. Use soft-faced mallet to tap vise so that indicator needles move one-half distance back toward zero (Figure 24)

(CAUTION: Tap the vise so that the jaw moves away from the indicator, never toward it.)

FIGURE 24



JOB SHEET #4

U. Reposition vise with indicator centered on solid jaw; zero indicator

V. Position vise with indicator near end of jaw where adjustment was made; note indicator reading

W. Repeat Steps T through V until indicator reads zero at each location

X. Tighten vise bolts securely, and then check to make sure that vise did not move while tightening

Y. Have instructor check vise alignment

(NOTE: You may want to practice this procedure several more times. Indicating the vise zero to one of the axes should be done in seven minutes or less.)

Z. Put away tools and clean work area

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #5 — ALIGN WORK MOUNTED TO TABLE

I. Equipment and materials

A. Horizontal mill with arbor and arbor support

B. Wrenches

C. T-nuts, flange nuts, and 3-inch long stud bolts

D. Hold-down clamps and step blocks

E. Matched parallels, 6" × 1/2" × 1"

F. Dial indicator with attachments

G. Clean rag

H. Cold rolled steel bar, SAE 1018, 3" × 12" × 3/4"

I. Combination square set

J. Soft-faced mallet

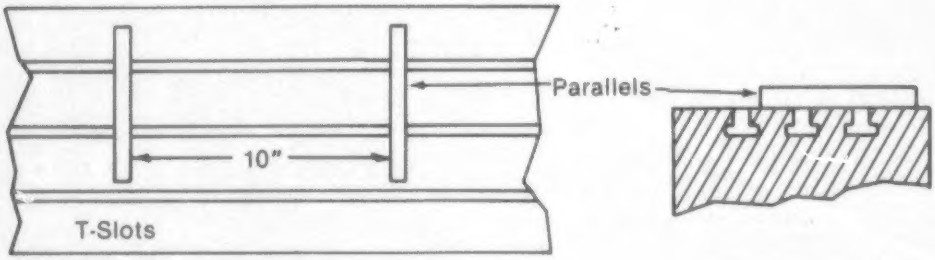
II. Procedure

A. Mount arbor in spindle and secure arbor support

B. Clean mill table with rag

C. Clean parallels, and set one 5 inches on each side of center of table with 1/2-inch surfaces on table approximately 90 degrees to T-slots (Figure 25)

FIGURE 25

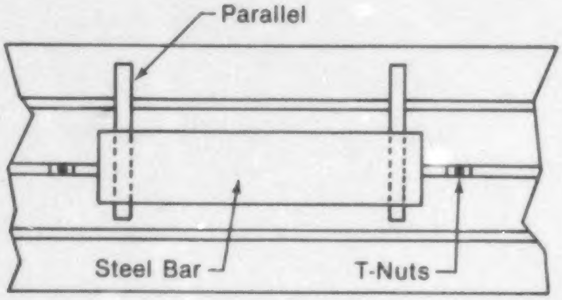


JOB SHEET #5

D. Slide T-nuts into center T-slot

E. Set steel bar on parallels so that about ½ inch extends beyond each side of parallels (Figure 26)

FIGURE 26


Parallel
Steel Bar
T-Nuts

F. Screw stud bolts about ½ inch into T-nuts

G. Place clamps over stud bolts and start flange nuts on stud bolts

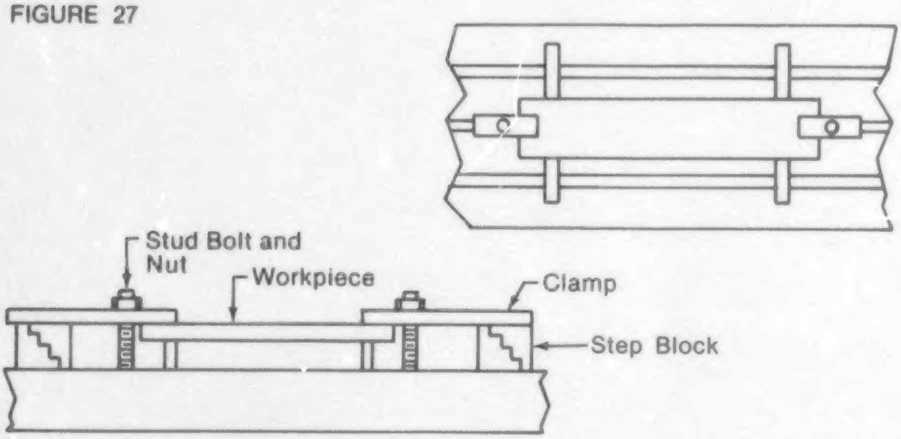
H. Select step blocks that will make up a 1¾-inch height

(NOTE: Step blocks should be slightly higher than top surface of workpiece.)

I. Set clamps on step blocks at each end of steel bar (Figure 27)

(NOTE: Stud bolts should be as close to work as possible.)

FIGURE 27

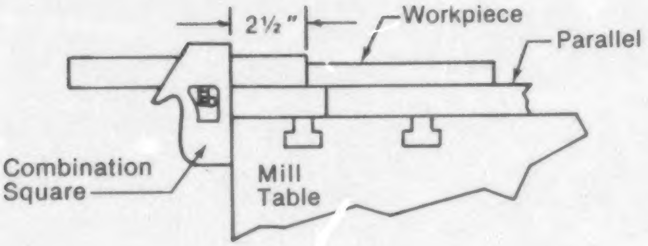

Stud Bolt and Nut
Workpiece
Clamp
Step Block

J. Use combination square to help rough align workpiece parallel to table

JOB SHEET #5

K. Set square head against table and slide blade to workpiece; tighten combination square (Figure 28)

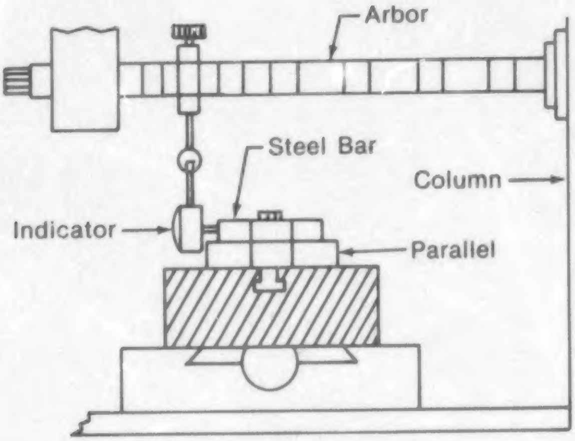
FIGURE 28


2½"
Workpiece
Parallel
Combination Square
Mill Table

L. Snug clamp at each end of workpiece

M. Mount indicator to arbor so that plunger of indicator points to front side of steel bar (Figure 29)

FIGURE 29


Arbor
Steel Bar
Column
Indicator
Parallel

N. Adjust table so that indicator plunger is on and near one end of steel bar

O. Crank table to move indicator near other end of bar

P. Note difference in readings

Q. Move table to place indicator at end of lower reading; zero indicator

R. Move table to place indicator at end of higher reading; note reading

JOB SHEET #5

S. Tap bar lightly to move it away from indicator until needle moves one-half distance to zero

(CAUTION: Always tap the workpiece so that it moves away from indicator, never toward it.)

T. Repeat steps N through S until zero reading is obtained at each end

U. Snug right then left clamps and flange nuts until tight

V. Check alignment again to make sure that bar did not move during tightening

W. Have instructor check alignment

X. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #6 — ALIGN ANGLE PLATE AT RIGHT ANGLE TO COLUMN

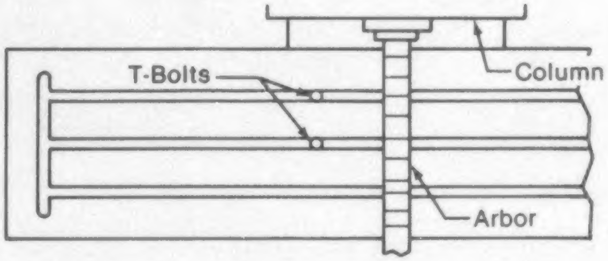
I. Tools and equipment

- A. Horizontal mill with arbor and arbor support
- B. Slotted angle plate, 6 inches
- C. Combination square
- D. Dial indicator
- E. T-bolts and flange nuts
- F. Clean rag
- G. Soft-faced mallet

II. Procedure

- A. Mount arbor in mill spindle and secure arbor support
- B. Clean mill table
- C. Clean angle plate and set on mill table
- D. Slide T-bolts in second and third T-slots to about middle of table (Figure 30)

FIGURE 30

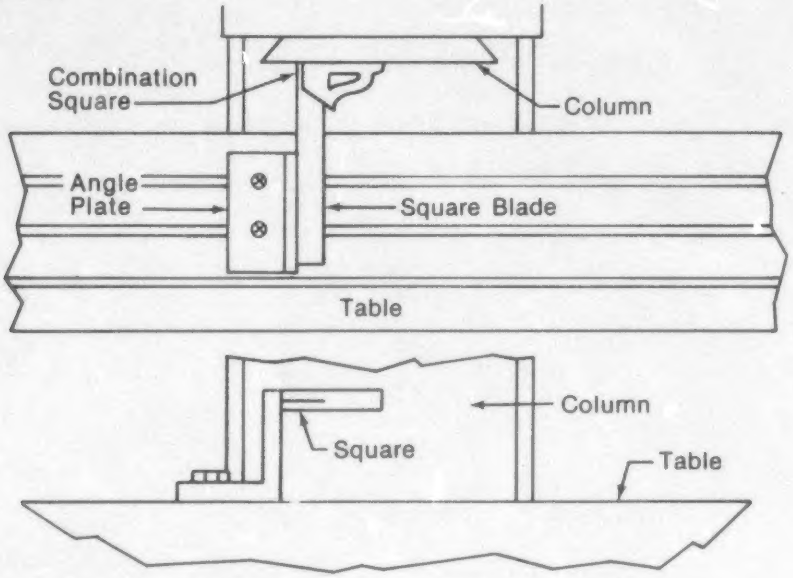


- E. Set slotted base of angle plate on T-bolts; screw on flange nuts

JOB SHEET #6

F. Place base of combination square firmly against column; slide face of angle plate against blade of square for rough alignment (Figure 31)

FIGURE 31

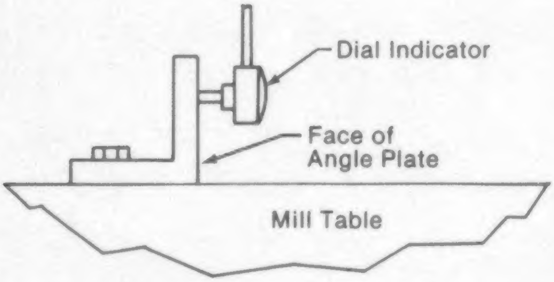

Combination Square
Column
Angle Plate
Square Blade
Table
Column
Square
Table

G. Tighten bolts until just snug

H. Secure dial indicator to arbor so that plunger points toward face of angle plate

I. Move table to bring plunger into contact with angle plate (Figure 32)

FIGURE 32


Dial Indicator
Face of Angle Plate
Mill Table

J. Move table so that indicator travels from one side of angle plate to the other; note reading at each end

K. Move table so that indicator is at side of lower reading; zero indicator

JOB SHEET #6

L. Move table to position indicator at side of higher reading; note difference

M. Gently tap angle plate so that angle plate moves away from indicator until needles move one-half distance toward zero

(CAUTION: Tap angle plate so that it moves away from indicator, never toward it.)

N. Repeat steps J through M until zero reading is obtained at each side

O. Tighten securing bolts and recheck alignment to make sure that angle plate did not move during tightening

P. Have instructor inspect your alignment

Q. Tear down setup; clean and store tools and equipment

(NOTE: This procedure may also be used to align a vise perpendicular to mill table.)

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #7 — MILL SQUARE A WORKPIECE MOUNTED IN VISE

I. Equipment and materials

- A. Horizontal mill with arbor and arbor support
- B. Swivel-base vise with T-bolts and flange nuts
- C. Plain helical mill cutter, 2$^1/_2$-inch diameter, 4 inches wide
- D. Clean rag
- E. Dial indicator with attachments
- F. Parallels, $^3/_4$" × $^3/_8$" × 6"
- G. Soft-faced mallet
- H. Piece of smooth cardboard
- I. Round mild steel bar, SAE 1018, $^1/_2$-inch diameter, 6 inches long
- J. Steel bar, SAE 1045, 2" × 2" × $^1/_2$"
- K. Micrometer, 1 to 2 inches
- L. File with handle
- M. Piece of paper

II. Procedure

- A. Peform daily maintenance procedures
- B. Mount arbor in mill spindle
- C. Mount vise and align parallel to table
- D. Position table 3 to 4 inches from column
- E. Mount cutter for clockwise rotation

  (NOTE: Make sure that spindle rotation is clockwise.)
- F. Put spacing collars and bushing on arbor
- G. Mount arbor support and secure to overarm

JOB SHEET #7

H. Adjust arbor support bushing and secure arbor nut

(CAUTION: Make sure that cutter and arbor bearing are properly keyed.)

I. Calculate and set spindle speed

J. Calculate and set feed

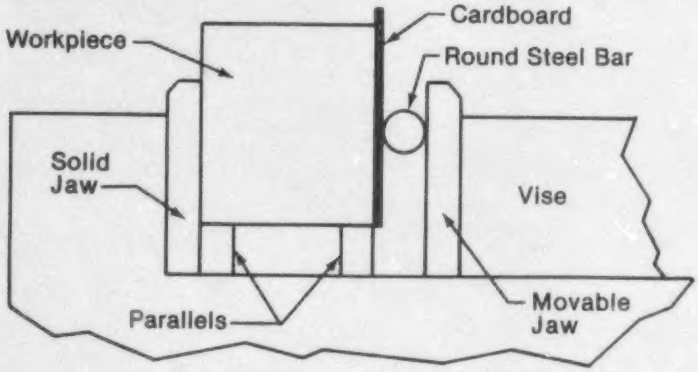
K. Have instructor check speed and feed settings

L. Set parallels in vise

M. Set workpiece on parallels with side against solid jaw

N. Place cardboard against other side of workpiece, and place round bar against cardboard; clamp with movable jaw (Figure 33)

FIGURE 33


Cardboard
Workpiece
Round Steel Bar
Solid Jaw
Vise
Parallels
Movable Jaw

O. Use handwheels to position workpiece under cutter

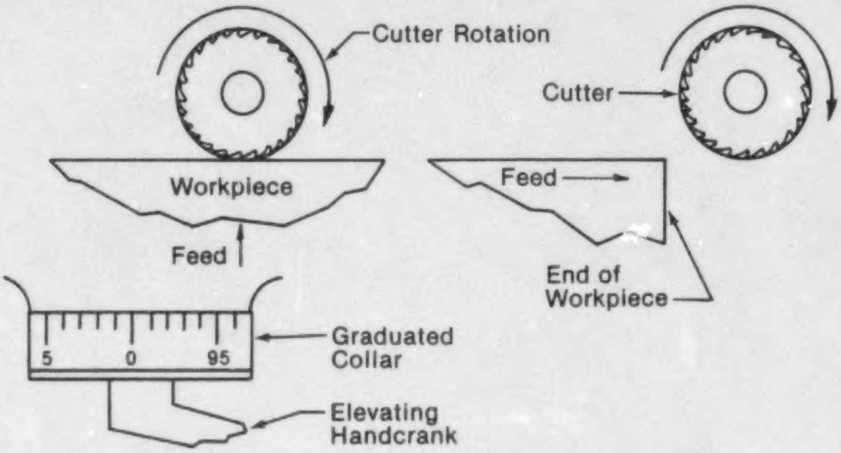
P. Start cutter rotating

Q. Crank up table slowly until corner begins to just shave workpiece; zero graduated collar

JOB SHEET #7

R. Crank down one-half revolution and move workpiece to left side of cutter (Figure 34)

FIGURE 34


Cutter Rotation
Cutter
Workpiece
Feed
Feed
End of Workpiece
5
0
95
Graduated Collar
Elevating Handcrank

S. Raise table 0.060 inch past zero

T. Turn on coolant and adjust flow

U. Engage power feed

V. Allow cutter to cut to end of workpiece

W. Lower table 0.015 inch

X. Reverse direction of feed

Y. Push rapid-traverse lever to return workpiece to starting place left of cutter

Z. Adjust table for a 0.034-inch cut

AA. Engage power feed and make second cut

BB. Lower table and move workpiece to starting position, using rapid traverse

CC. Remove workpiece; deburr

DD. Place workpiece in vise with side just cut against solid jaw, and steel bar between workpiece and movable jaw; tighten vise, but do not seat work

EE. Repeat steps O through BB for second side

JOB SHEET #7

FF. Remove workpiece; deburr

GG. Place part back in vise so that side just cut is against solid jaw and first side cut is resting on parallels

HH. Place round bar between workpiece and movable jaw

II. Secure vise and seat workpiece on parallels with mallet

JJ. Repeat steps O through V for third side

KK. Stop spindle and measure thickness with micrometer

LL. Subtract 1.812 inches from micrometer reading obtained to determine amount of next cut

MM. Raise table required amount and make finish cut

NN. Lower table and move cutter to starting point

OO. Remove workpiece and deburr

PP. Place workpiece in vise with uncut side up; secure in vise and seat with mallet

(NOTE: Do not use round bar.)

QQ. Repeat steps O through V for fourth side

RR. Repeat steps KK and LL for fourth side

SS. Remove workpiece; deburr

TT. Check for squareness, and then turn in workpiece to instructor for inspection

UU. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #8 — PERFORM FACE MILLING OPERATION USING STYLE "C" ARBOR

I. Equipment and materials

- A. Horizontal milling machine
- B. Style "C" arbor
- C. Face mill cutter, 4-inch diameter
- D. Combination square set with 12-inch blade
- E. Dial indicator with magnetic base and attachments
- F. Clean rag
- G. Step blocks and hold-down clamps with required fasteners
- H. Soft-faced mallet
- I. Steel bar machined square (from Job Sheet #7)
- J. Adjustable wrench, 12 inches

II. Procedure

- A. Perform daily maintenance procedures
- B. Slide T-nuts into front and middle T-slots near center of table; screw in stud bolts, place clamps on bolts, and start flange nuts
- C. Set workpiece on table 90 degrees to T-slots, with end of steel bar extending 1 inch beyond edge of table
- D. Set base of combination square against column; slide workpiece up to blade
- E. Adjust clamps to height of bar; snug nuts
- F. Place magnetic base on underside of overarm
- G. Secure dial indicator to indicator post, with plunger pointing toward workpiece
- H. Indicate workpiece square to table
- I. Tighten flange nuts and check squareness
- J. Mount style "C" arbor and secure cutter to arbor

JOB SHEET #8

K. Calculate and set speed

L. Calculate and set feed

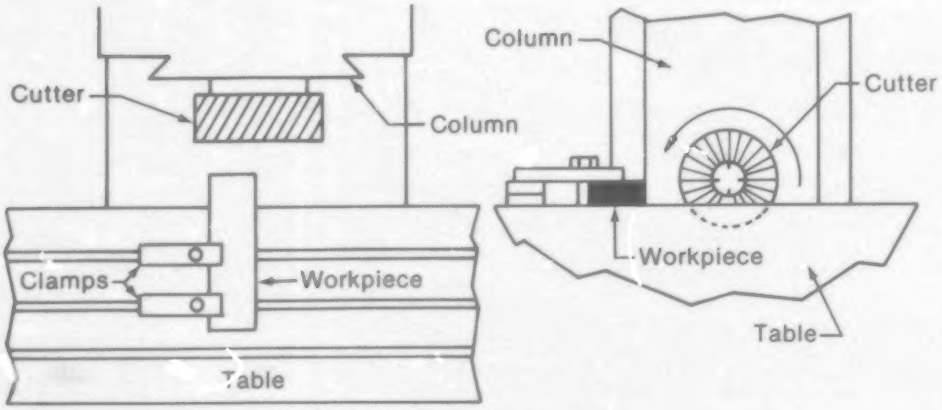
M. Have instructor check speed and feed settings

N. Move cutter near end of workpiece, and center work vertically by raising table

O. Start spindle; feed workpiece slowly until cutter just shaves workpiece

P. Zero graduated collar of traversal handwheel (Figure 35)

FIGURE 35



Q. Move workpiece to left side of cutter

(NOTE: Cut pressure should be toward the clamps and down against the table.)

R. Advance traversal feed 0.100 inch

S. Start spindle

T. Start coolant motor and adjust coolant flow

U. Engage longitudinal power; make cut

V. Move workpiece back to left side of cutter and stop spindle

W. Remove workpiece; deburr

JOB SHEET #8

X. Check for squareness

Y. Turn part end for end and repeat steps C through W

Z. Turn in workpiece to instructor for inspection

AA. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #9 — MILL A KEYWAY WITH STAGGERED-TOOTH MILL CUTTER

I. Equipment and materials

- A. Horizontal mill with arbor and arbor support
- B. Vise with or without swivel base and mounting bolts
- C. Staggered-tooth mill cutter, $^3/_8$-inch, 4-inch diameter
- D. Dial indicator with attachments
- E. Combination square with 12-inch blade
- F. Clean rag
- G. Round steel bar, SAE 1020, $1^1/_2$-inch diameter, 8 inches long
- H. Steel rule, 6 inches
- I. Soft-faced mallet
- J. Piece of paper

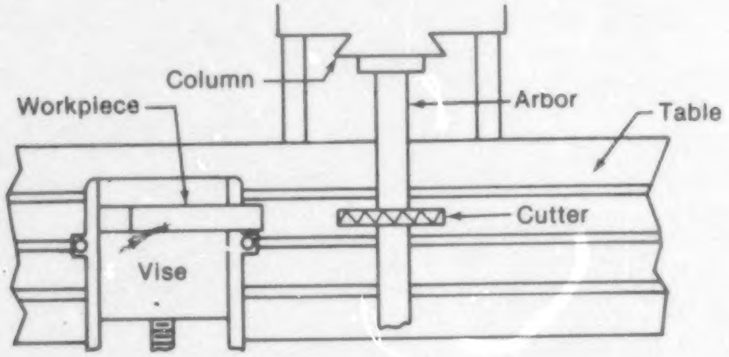
II. Procedure

- A. Perform daily maintenance procedures
- B. Mount arbor
- C. Mount and align vise parallel to T-slots
- D. Mount cutter about 6 inches from column for clockwise rotation
- E. Mount arbor support and adjust arbor bushing
- F. Secure arbor support and tighten arbor nut

JOB SHEET #9

G. Place workpiece in vise with 3 inches extending from right side of vise (Figure 36)

FIGURE 36


Column
Workpiece
Arbor
Table
Cutter
Vise

H. Calculate and set speed

I. Calculate and set feed

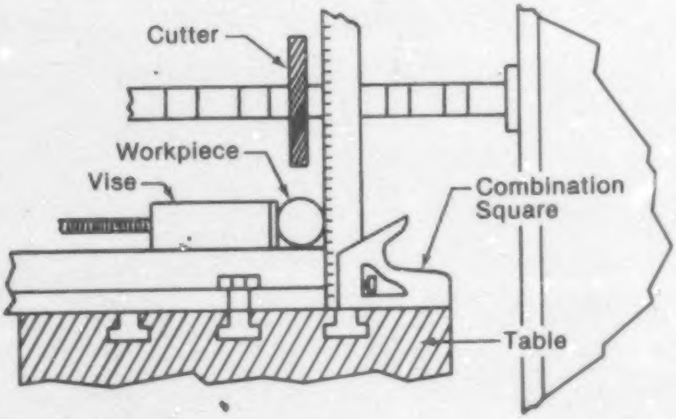
J. Have instructor check speed and feed settings

K. Center workpiece under cutter

1. Procedure using combination square

   a. Place base of combination square on table with blade touching workpiece (Figure 37)

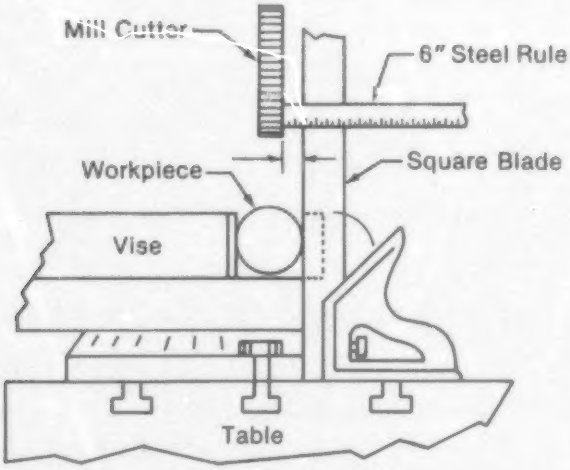
FIGURE 37


Cutter
Workpiece
Vise
Combination Square
Table

JOB SHEET #9

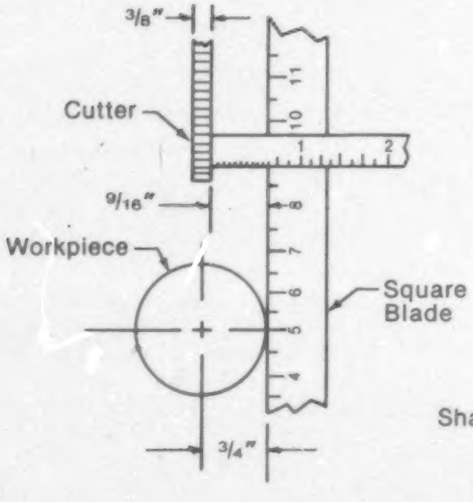
b. Hold square firmly in place, and with steel rule measure distance from combination square blade to cutter (Figure 38)

FIGURE 38


Mill Cutter
6" Steel Rule
Workpiece
Square Blade
Vise
Table

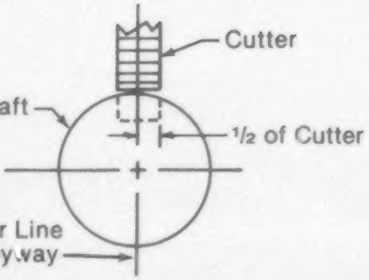
c. Crank table in or out until distance is radius of workpiece less one-half thickness of cutter (Figure 39)

FIGURE 39


3/8"
Cutter
9/16"
Workpiece
Square Blade
3/4"

3/4" = Radius of Shaft
−3/16" = One-half Thickness of Cutter

9/16" = Measurement 6-inch steel rule should read to place center of cutter to center of shaft.

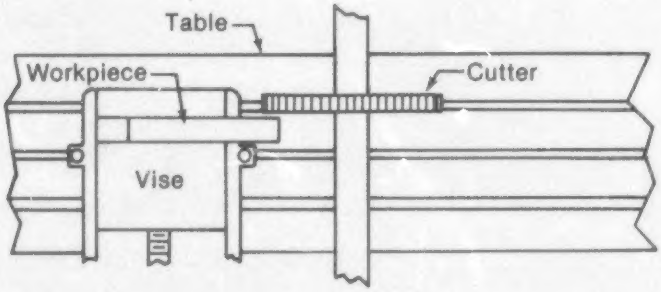

Cutter
Shaft
1/2 of Cutter
Center Line for Keyway

JOB SHEET #9

2. Procedure using cutter to locate center of workpiece

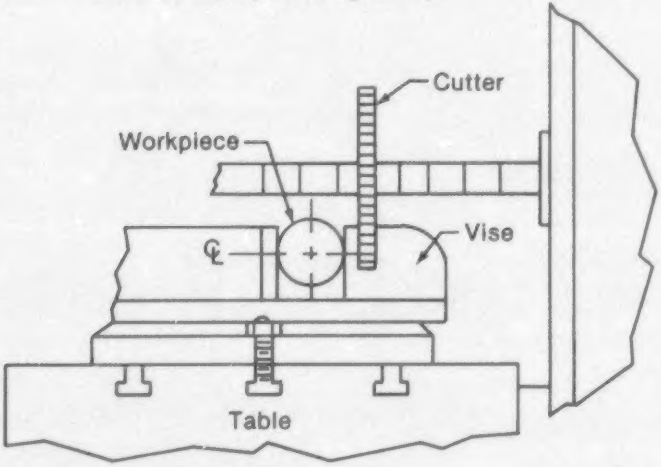
   a. Position workpiece so that cutter is toward column to right of workpiece (Figure 40)

FIGURE 40



   b. Raise table so that bottom of cutter is lower than horizontal center of workpiece (Figure 41)

FIGURE 41



   c. Start cutter rotating

   d. With one hand, hold piece of paper between workpiece and cutter; with other hand, crank cross-feed handwheel until cutter just starts to cut paper

   e. Lower table; zero graduated collar of cross feed

   f. Crank cross-feed handwheel to move cutter over workpiece a distance equal to radius of workpiece plus one-half thickness of cutter and 0.002 inch for thickness of paper

JOB SHEET #9

L. Start spindle

M. Raise table by hand until cutter just shaves workpiece

N. Zero elevating crank graduated collar

O. Move table until cutter clears end of workpiece

P. Raise table an amount equal to the depth of keyway

(NOTE: Depths of keyways are listed in machining reference books.)

Q. Turn on coolant and adjust flow

R. Engage longitudinal power feed and allow cutter to cut through workpiece

S. Lower table to clear workpiece from cutter

T. Reverse power feed, engage rapid traverse, and move table to starting point (cutter on right side of work)

U. Stop power feed

V. Stop spindle

W. Check depth of cut; repeat steps K through V if cut is not deep enough

X. Deburr workpiece; turn in workpiece to instructor for inspection

Y. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #10 — PERFORM A STRADDLE MILLING OPERATION

I. Equipment and materials

- A. Horizontal mill with arbor and arbor support
- B. Vise, 6-inch, and mounting bolts
- C. Two staggered-tooth mill cutters, 6-inch diameter, 1/2-inch thick
- D. Micrometer, 6 to 7 inches
- E. Micrometer, 0 to 1 inch
- F. Spacers for arbor, assorted lengths
- G. Steel bar from Job Sheet #8
- H. Dial indicator with attachments
- I. Combination square with 12-inch blade
- J. Clean rag
- K. Set of parallels, 1/2" × 1" × 6"
- L. Wrenches for arbor, vise, and arbor support
- M. Soft-faced mallet

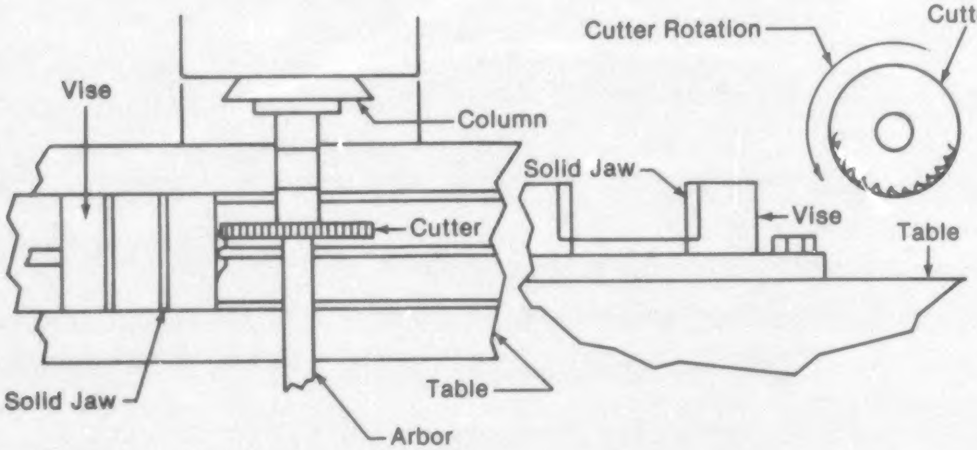
II. Procedure

- A. Perform daily maintenance procedure
- B. Mount arbor
- C. Mount vise perpendicular to table with solid jaw to right

JOB SHEET #10

D. Mount cutter so that it rotates counterclockwise 4 inches from arbor driving lugs (Figure 42)

FIGURE 42

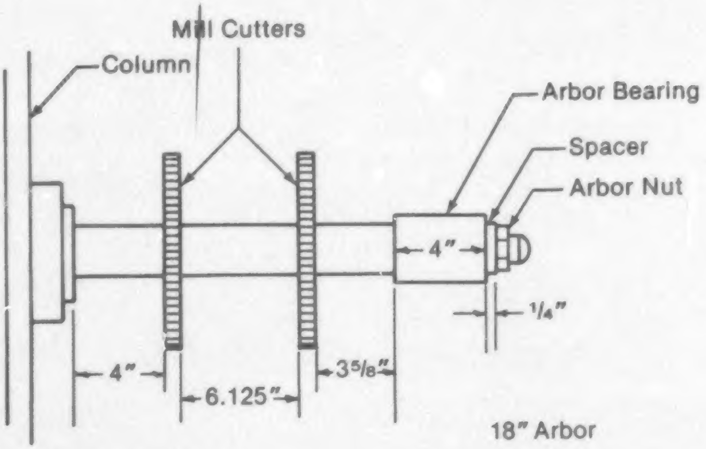

Cutter Rotation
Cutter
Vise
Column
Solid Jaw
Cutter
Vise
Table
Solid Jaw
Table
Arbor

E. Measure spacers with micrometer to allow spacing of 6.125 inches

F. Slide spacers onto arbor; then slide on other cutter

G. Add additional spacers; mount arbor bearing and secure (Figure 43)

FIGURE 43


Mill Cutters
Column
Arbor Bearing
Spacer
Arbor Nut
4″
1/4″
4″
6.125″
3 5/8″
18″ Arbor

H. Calculate and set speed

JOB SHEET #10

I. Calculate and set feed

J. Have instructor check speed and feed settings

K. Seat workpiece on 1-inch parallels and secure vise

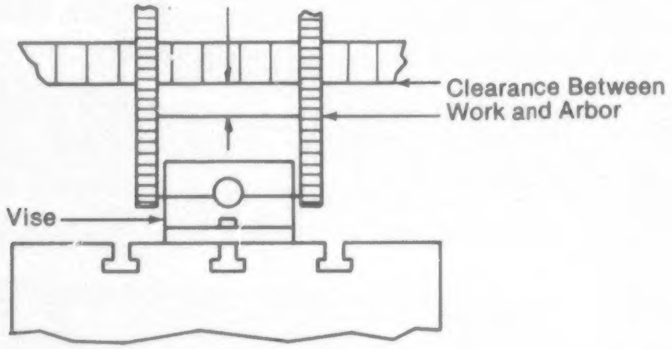
L. Remove vise handle

M. Center workpiece between the two cutters

N. Clear cutters by moving table; raise table 2.050 inches to position workpiece

O. Make sure that top surface of workpiece clears arbor and that cutters clear vise (Figure 44)

FIGURE 44



P. Start spindle

Q. Start and adjust coolant

R. Engage power feed and make cut

S. Allow workpiece to clear cutters and stop machine

T. Remove workpiece

U. Deburr workpiece; turn in workpiece to instructor for inspection

V. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #11 — MILL AN ANGLE WITH SINGLE-ANGLE MILL CUTTER

I. Equipment and materials

   A. Horizontal mill with arbor and arbor support

   B. Vise and mounting bolts

   C. Wrenches for arbor, vise, and arbor support

   D. Set of parallels, ½" × 1" × 6"

   E. Dial indicator with attachments

   F. Clean rag

   G. Soft-faced mallet

   H. Steel bar from Job Sheet #10

   I. Steel rule, 6 inches

   J. Single mill cutter, 45-degree angle, 4-inch diameter, ¾-inch thick

   K. Piece of paper

II. Procedure

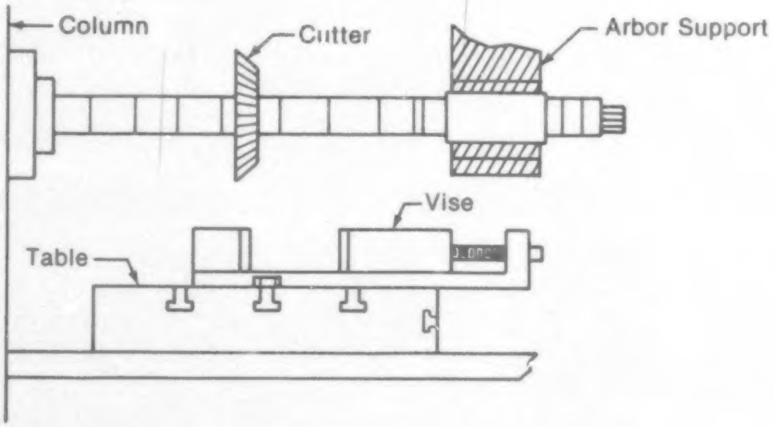
   A. Perform daily maintenance procedures

   B. Mount arbor

   C. Mount and align vise so that solid jaw is parallel to table

   D. Mount cutter 4 inches from arbor driving lugs (Figure 45)

FIGURE 45



JOB SHEET #11

E. Add additional spacers to mount arbor bearing 5 inches from cutter, and complete arbor installation; secure

F. Mount workpiece in vise and seat on parallels

G. Calculate and set speed

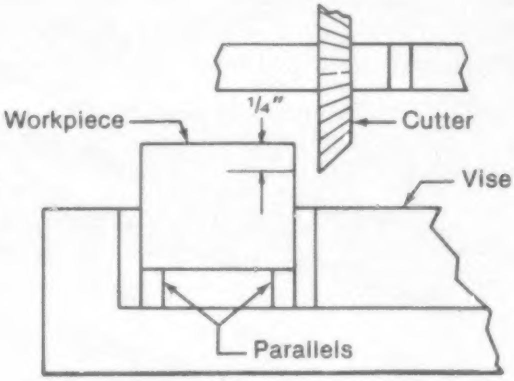
H. Calculate and set feed

I. Have instructor check speed and feed settings

J. Start spindle

K. Raise table so that cutter is 1/4 inch below top surface of workpiece (Figure 46)

FIGURE 46

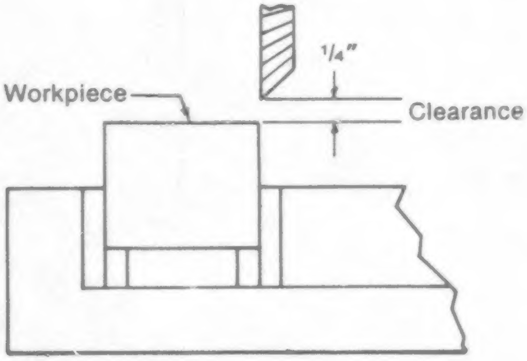


L. With one hand, hold piece of paper between workpiece and cutter; with other hand, crank traversal-feed handwheel slowly until cutter starts to cut paper

M. Zero traversal graduated collar

N. Lower table until cutter clears top surface of workpiece by 1/4 inch (Figure 47)

FIGURE 47



JOB SHEET #11

O. Move table one-half width of workpiece so that cutter is centered over workpiece

P. Raise table until cutter just shaves workpiece; zero elevating graduated collar

Q. Lower table 0.015 inch and crank cross-feed handwheel to clear cutter so that workpiece can be fed into cutter against direction of rotation

R. Raise table 0.125 inch

S. Turn on and adjust coolant

T. Engage power feed and allow cutter to cut length of workpiece

U. Clear cutter and reverse feed direction

V. Use rapid traverse to return cutter to starting point; stop feed

W. Raise table another 0.125 inch and make second cut

X. Continue making 0.125-inch cuts until cut is 0.625 inch deep

Y. Make finish cut by raising cutter 0.026 inch and feeding workpiece through cutter

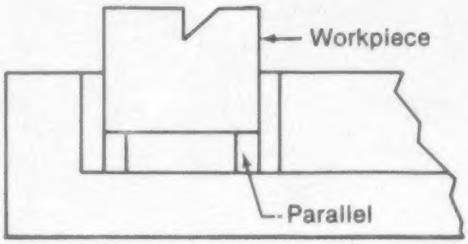
Z. Reverse feed direction and allow cutter to feed back through cut

AA. Stop feed when workpiece reaches starting point

BB. Stop spindle and remove workpiece

CC. Place side that was against adjustable jaw against solid jaw, with the angular cut up; tighten vise and seat workpiece (Figure 48)

FIGURE 48



DD. Repeat steps L through BB

EE. Deburr workpiece; turn in workpiece to instructor for inspection

FF. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

JOB SHEET #12 — MILL TO BLUEPRINT SPECIFICATIONS USING MACHINE CONTROLS

I. Equipment and materials

A. Horizontal mill with arbor and arbor support

B. Vise and mounting bolts

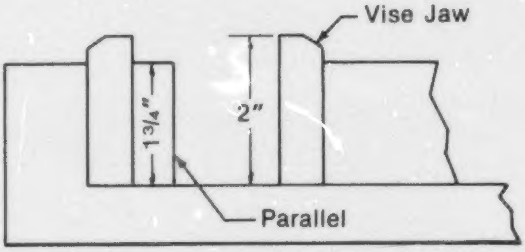
C. Dial indicator with attachments

D. Clean rag

E. Set of parallels 1/2 inch by 6 inches (Figure 49)

(NOTE: Height of parallels will vary with height of vise jaw. Parallels should be 1/4 inch below top of vise jaw.)

FIGURE 49



F. Staggered-tooth mill cutter, 5 to 6 inches in diameter, 1/2-inch thick

G. Slitting saw, 3/16-inch wide, 4 to 5 inches in diameter

H. Aluminum block, SAE 2024 T4, 3/4" × 2 1/2" × 3"

I. Soft-faced mallet

J. File with handle

K. Wrenches for arbor, vise, and arbor support

L. Piece of paper

II. Procedure

A. Perform daily maintenance procedures

B. Mount arbor

JOB SHEET #12

C. Mount and align vise parallel to table

D. Mount staggered-tooth cutter 5 inches from arbor drive lugs

E. Complete arbor installation and secure

F. Place workpiece on parallels; tighten vise and seat work on parallels

G. Calculate and set speed

H. Calculate and set feed

I. Have instructor check speed and feed settings

J. Position workpiece under cutter so that cutter will clear side next to movable jaw

K. Raise table so that cutter is 1/8 inch below top surface of workpiece

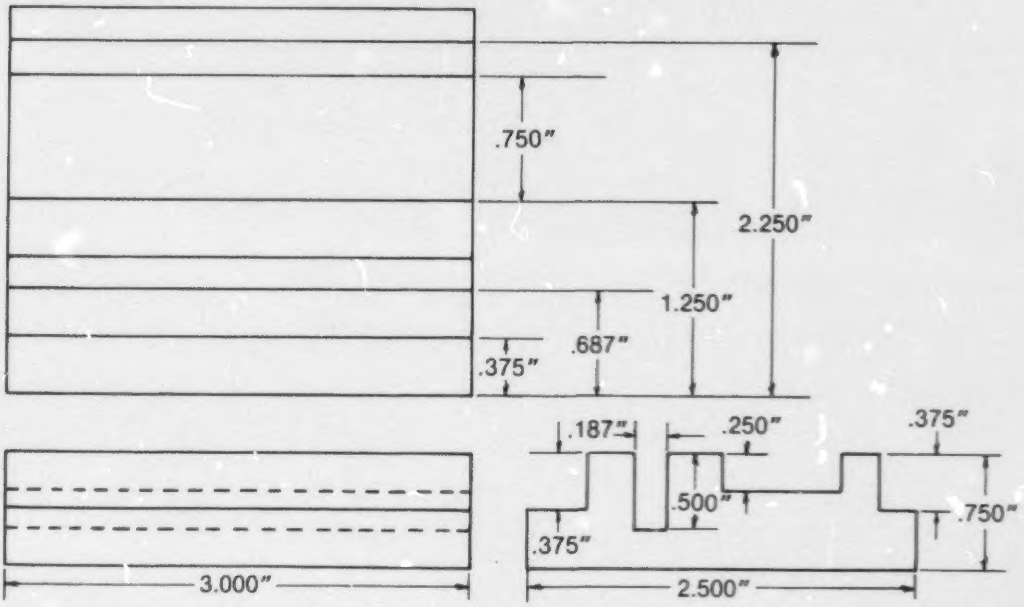
L. Move workpiece toward cutter with traversal-feed handwheel until cutter starts to shave side

M. Zero graduated collar

N. Lower table so that cutter will clear top surface of workpiece

O. Study machining specifications below (Figure 50)

FIGURE 50



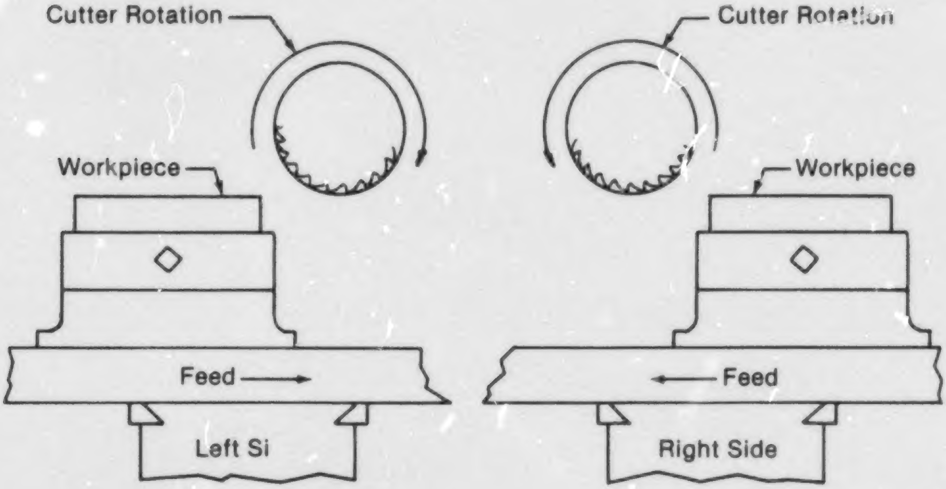
JOB SHEET #12

P. Raise table so that cutter starts to shave workpiece; zero elevating graduated collar

Q. Lower table 0.015 inch

R. Position workpiece for conventional milling by moving it to right or left side of cutter (Figure 51)

FIGURE 51


Cutter Rotation
Cutter Rotation
Workpiece
Workpiece
Feed
Feed
Left Si
Right Side

S. Raise table 0.375 inch past zero setting

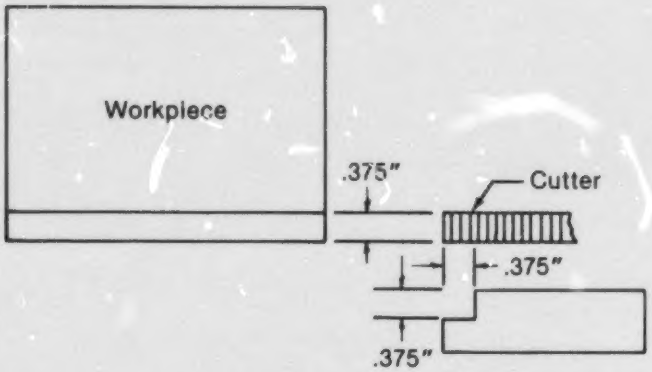
T. Start coolant and adjust flow

U. Engage longitudinal power feed and allow cutter to feed through workpiece

JOB SHEET #12

V. Lower table 0.015 inch past zero setting; rapid reverse back to starting point (Figure 52)

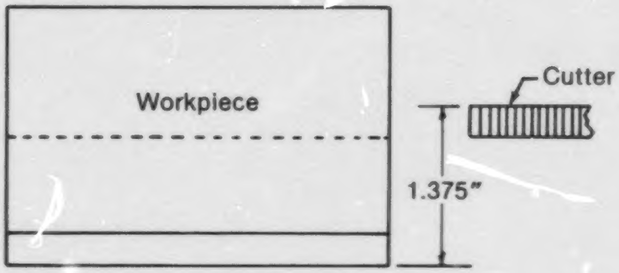
FIGURE 52


Workpiece
.375"
Cutter
.375"
.375"

W. Move workpiece forward another 1.375 inches

X. Raise table 0.250 inch past zero setting (Figure 53)

FIGURE 53


Workpiece
Cutter
1.375"

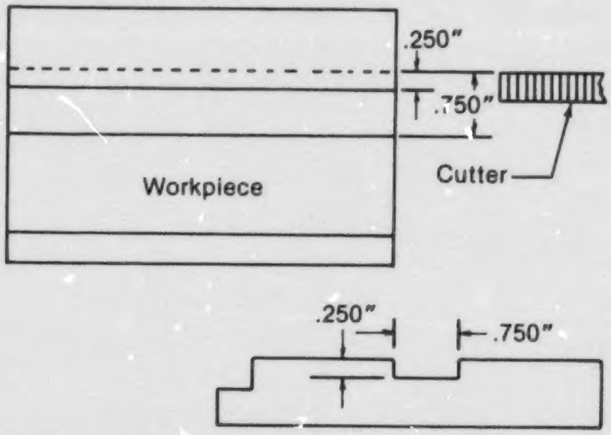
Y. Engage power feed and allow cutter to cut length of workpiece

Z. Stop feed, clear cutter, and move workpiece to starting place

JOB SHEET #12

AA. Move workpiece forward 0.250 inch, and finish cutting slot to width (Figure 54)

FIGURE 54


.250"
.750"
Cutter
Workpiece
.250"
.750"

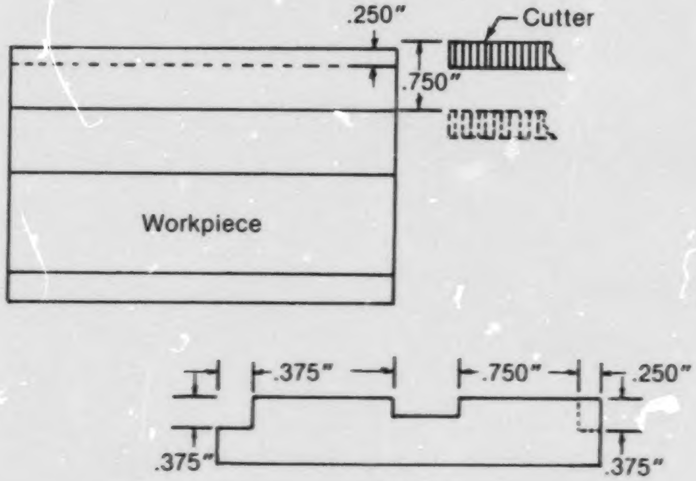
BB. Move table back to starting point

CC. Raise table 0.125 inch

(NOTE: The table is now 0.375 inch above zero position.)

DD. Move workpiece forward 0.750 inch (Figure 55)

FIGURE 55


.250"
Cutter
.750"
Workpiece
.375"
.750"
.250"
.375"
.375"

JOB SHEET #12

EE. Engage power feed and allow cutter to cut length of workpiece

FF. Stop machine and remove cutter

GG. Place slitting saw on arbor and secure

HH. Calculate and set speed

II. Calculate and set feed

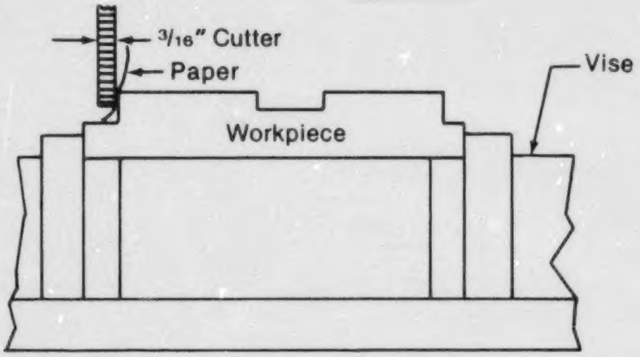
JJ. Have instructor check speed and feed settings

KK. Position cutter over first cut made with staggered-tooth cutter, with bottom of cutter about 1/8 inch below top surface of workpiece

LL. Start spindle

MM. With one hand, hold piece of paper between cutter and workpiece; with other hand, feed table with cross-feed handwheel until cutter begins shaving paper (Figure 56)

FIGURE 56



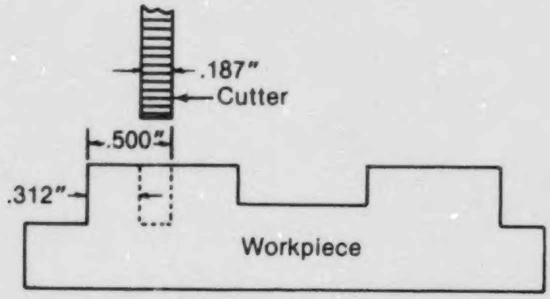
NN. Zero cross-feed graduated collar

OO. Lower table until cutter clears top surface of workpiece

JOB SHEET #12

PP. Move table forward 0.500 inch (Figure 57)

FIGURE 57



QQ. Raise table until cutter shaves workpiece; zero elevating graduated collar

RR. Lower table 0.015 inch; move workpiece longitudinally clear of cutter

SS. Raise table 0.500 inch past zero setting

TT. Engage power feed and allow cutter to cut length of workpiece

UU. Stop spindle and remove workpiece

VV. Deburr workpiece; turn in workpiece to instructor for inspection

WW. Tear down setup; clean and store tools and equipment

HORIZONTAL MILLING MACHINES
UNIT II

TEST

NAME ____ SCORE ________________

1. Match to their correct definitions terms associated with horizontal milling machines. Write the correct numbers in the blanks.

______a. To prepare the machine prior to performing a particular operation

______b. To set correct relative position between cutter axis and workpiece

______c. Center line of cutter rotation

______d. To align by using dial indicator

______e. To align at 90-degree angle

______f. To set a workpiece solidly in work-holding device

______g. Direction spindle revolves as viewed from front of machine; referred to as right-hand (clockwise) or left-hand (counterclockwise)

______h. Accurately machined bars with adjacent sides square to each other and opposite sides parallel; made in matched sets; used to support workpiece when machining or setting up

______i. Thin pieces of metal, usually steel, used to level or align workpiece or work-holding device when setting up

______j. Process of dividing a circular or straight part into exact divisions

______k. T-shaped groove machined into tables and attachments to allow the use of bolts and nuts when mounting work-holding devices or accessories

______l. Curved path that advances at a uniform rate along a cylinder

______m. Special holder that may hold from one to six tool blanks

______n. Method of describing the diameter, width, and hole or shank size of a mill cutter

1. Square
2. Fly-cutter
3. Axis
4. Parallels
5. Cutter size
6. Set up
7. Seat
8. T-slot
9. Indicate
10. Shims
11. Helix
12. Align
13. Indexing
14. Spindle rotation

TEST

2. Name types of horizontal milling operations.

   a. ______________________ — Machining a surface that is parallel to face of cutter

   b. ______________________ — Milling a recess with an arbor-mounted or spindle-mounted cutter

   c. ______________________ — Using two arbor-mounted cutters to make two parallel cuts in one operation

   d. ______________________ — Milling a flat surface using the peripheral teeth of an arbor-mounted mill cutter

   e. ______________________ — Machining the end of workpiece with a cutter having side-cutting teeth

   f. ______________________ — Dividing a workpiece into equal spaces, angles, or divisions about an axis, using a dividing head to rotate workpiece

   g. ______________________ — Using a number of cutters to cut several surfaces in one operation

   h. ______________________ — Producing or enlarging a hole with a bit or boring tool mounted in spindle of horizontal milling machine

(NOTE: Test questions 3 and 4 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

3. List horizontal milling operations required to make parts.

4. Demonstrate ability to

   a. Mount a style "A" or "B" arbor and adjust arbor support bushing.
   b. Use machine controls properly.
   c. Mount cutter to arbor.
   d. Mount and align swivel-base vise.
   e. Align work mounted to table.
   f. Align angle plate at right angle to column.

TEST

g. Mill square a workpiece mounted in vise.

h. Perform face milling operation using style "C" arbor.

i. Mill a keyway with staggered-tooth mill cutter.

j. Perform a straddle milling operation.

k. Mill an angle with single-angle mill cutter.

l. Mill to blueprint specifications using machine controls.

HORIZONTAL MILLING MACHINES
UNIT II

ANSWERS TO TEST

1.	a.	6	h.	4
	b.	12	i.	10
	c.	3	j.	13
	d.	9	k.	8
	e.	1	l.	11
	f.	7	m.	2
	g.	14	n.	5

2. a. Face milling
   b. Slotting (grooving)
   c. Straddle milling
   d. Slab milling (plain milling)
   e. Side milling
   f. Indexing
   g. Gang milling
   h. Drilling (boring)

3. Evaluated to the satisfaction of the instructor

4. Performance skills evaluated to the satisfaction of the instructor

VERTICAL MILLING MACHINES
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to set up and operate a vertical mill. This knowledge will be shown by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with vertical milling machines.
2. Identify vertical milling operations.
3. Demonstrate the ability to
    a. Mount and remove cutters and cutter holders for vertical spindle machines.
    b. Use machine controls properly.
    c. Mount and align vise.
    d. Align head square to table.
    e. Perform a side milling operation.
    f. Perform an end milling operation.
    g. Mill a key seat with keyseat cutter and a key slot with end mill.
    h. Mill a rectangular pocket.
    i. Perform precision locating, drilling, and reaming of holes.
    j. Align a bore concentric to the spindle.
    k. Perform a boring operation.
    l. Perform drilling and milling operations using dividing head.

VERTICAL MILLING MACHINES
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Discuss unit and specific objectives.
- D. Discuss information and assignment sheets.
- E. Provide students with job sheets.
- F. Provide alternate jobs or change job sheets to fit equipment in your shop if necessary.
- G. Demonstrate and discuss procedures outlined in job sheets.
- H. Give test.
- I. Reteach and retest if necessary.

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Assignment Sheet #1 — List Required Milling Operations
- E. Answers to assignment sheet
- F. Job sheets
    1. Job Sheet #1 — Mount and Remove Cutters and Cutter Holders for Vertical Spindle Machines
    2. Job Sheet #2 — Use Machine Controls Properly
    3. Job Sheet #3 — Mount and Align Vise
    4. Job Sheet #4 — Align Head Square to Table
    5. Job Sheet #5 — Perform a Side Milling Operation
    6. Job Sheet #6 — Perform an End Milling Operation

SUGGESTED ACTIVITIES

7. Job Sheet #7 — Mill a Key Seat with Keyseat Cutter and a Key Slot with End Mill
8. Job Sheet #8 — Mill a Rectangular Pocket
9. Job Sheet #9 — Perform Precision Locating, Drilling, and Reaming of Holes
10. Job Sheet #10 — Align a Bore Concentric to the Spindle
11. Job Sheet #11 — Perform a Boring Operation
12. Job Sheet #12 — Perform Drilling and Milling Operations Using Dividing Head

G. Unit test

H. Answers to test

III. Unit references

A. Kibbe, Richard R., et. al. *Machine Tool Practices.* New York: John Wiley and Sons, 1979.

B. Krar, S.F., and J.W. Oswald, and J.E. St. Amand. *Technology of Machine Tools.* Toronto: McGraw-Hill of Canada, 1969.

C. Olivio, Thomas C. *Fundamentals of Machine Technology.* Belmont, California: Wadsworth Publishing Company, Inc., 1981.

VERTICAL MILLING MACHINES
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Collet — Hardened-steel sleeve with threads on one end used to hold standard-diameter tool shanks

(CAUTION: Damage to the collet will occur if the shank of the tool is not in the range of the collet.)

B. Cam-lock adapter — Device installed in spindle that provides for quickly securing or removing cutting tools by turning a spring-loaded cam

C. Spindle direction — Clockwise or counterclockwise direction of spindle rotation

D. Chip flow — Movement of chips away from cutter and workpiece; caused by use of cutting fluid

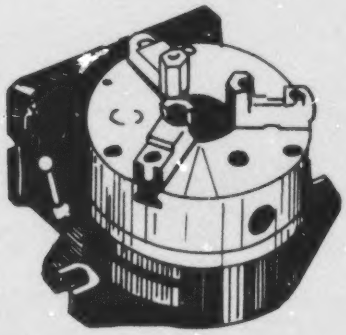
E. Teeth marks — Deviations from a perfect plain surface caused by cutting action

F. Finish cut — Final cut to a surface to obtain desired smoothness

G. Super spacer — Work-holding device mounted to milling machine with chuck in vertical or horizontal position; designed to be used with indexing plate by moving in uniform increments for rapid indexing (Figure 1)

EXAMPLE:

FIGURE 1



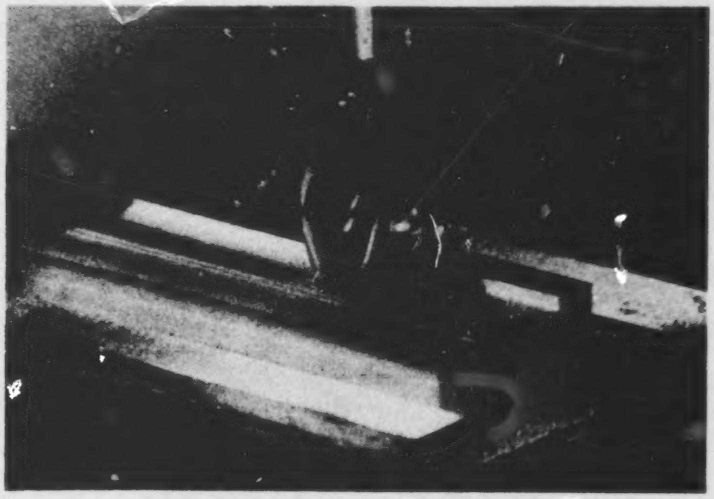
INFORMATION SHEET

II. Vertical milling operations (Figures 2-12; Assignment Sheet #1)

A. End milling — Milling a surface at 90 degrees to axis of spindle by using a solid-shank cutting tool or an adapter-held shell end mill

EXAMPLE:

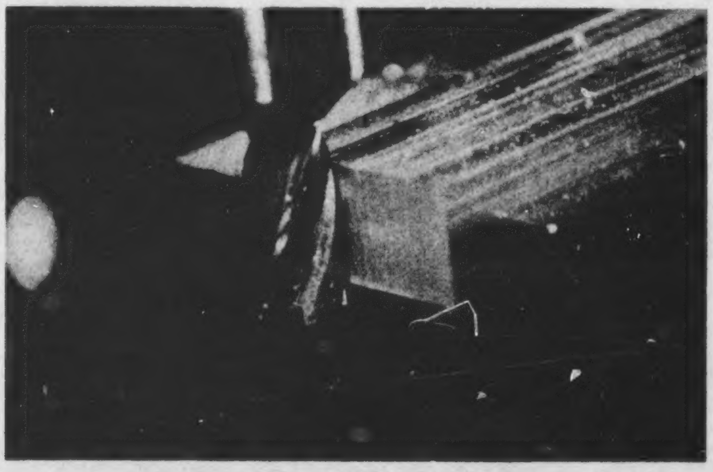
FIGURE 2



B. Side end milling — Milling a surface parallel to axis of spindle by using periphery of end mill or shell mill cutter

EXAMPLE:

FIGURE 3

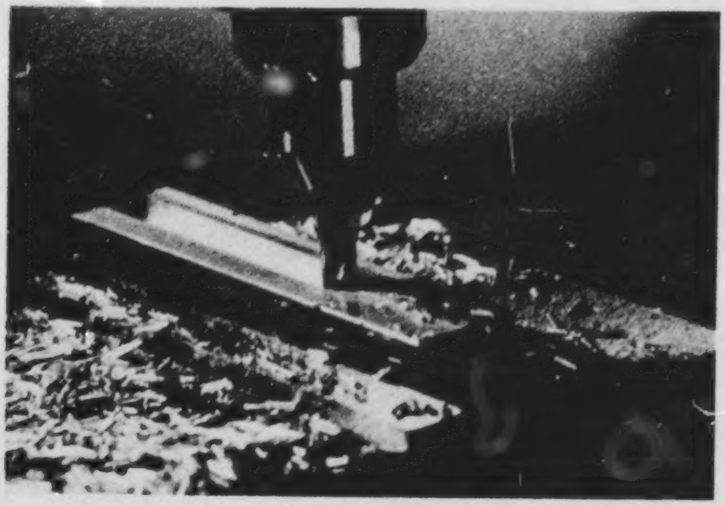


INFORMATION SHEET

C. Slotting — Producing a recess with a flat bottom and straight sides

EXAMPLE:

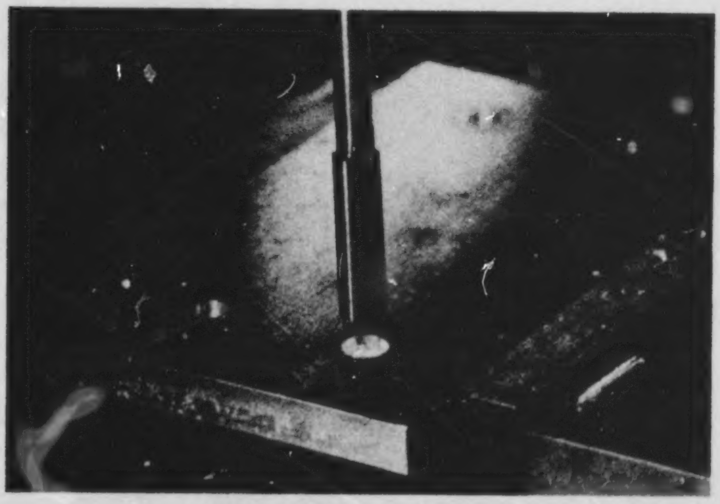
FIGURE 4



D. Drilling or reaming holes — Producing or finishing holes that require precise locations

EXAMPLE:

FIGURE 5

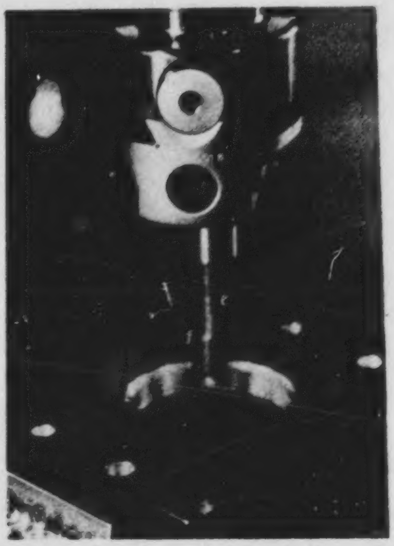


INFORMATION SHEET

E. Boring — Using a single-point tool to enlarge a hole by means of an adjustable head

EXAMPLE:

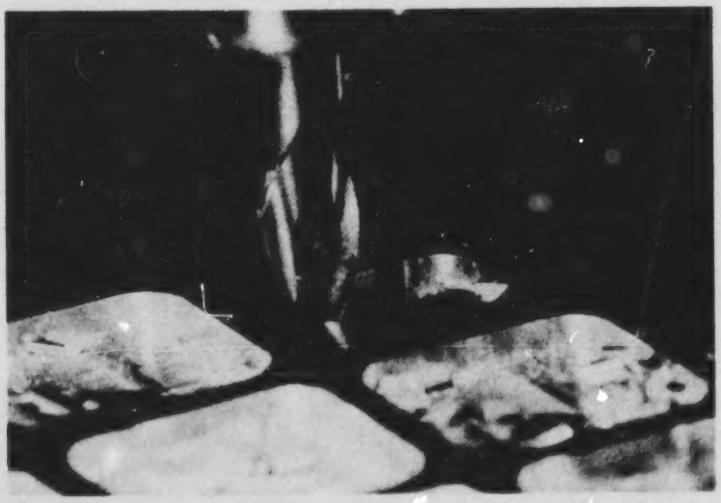
FIGURE 6



F. Pocket milling — Cutting a recess with a flat bottom and straight walls, or flat bottom and straight walls joined with a fillet

EXAMPLE:

FIGURE 7



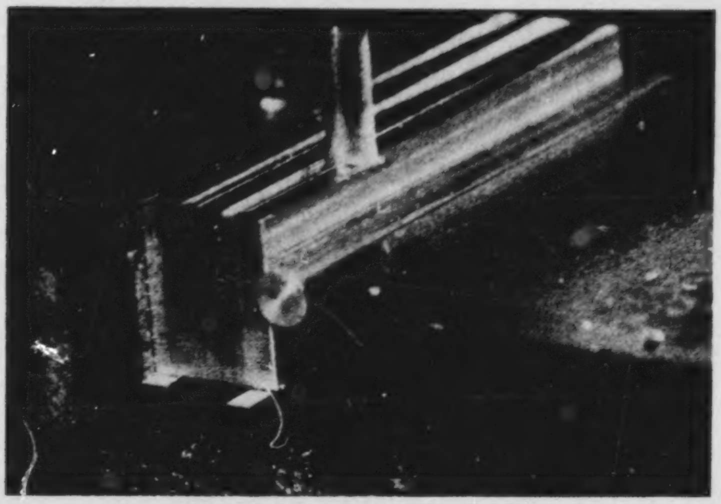
INFORMATION SHEET

G. Squaring — Cutting surfaces of a workpiece at 90-degree angles to each other

(NOTE: Squaring the sides of a workpiece is done with an end mill by rotating the work in the vise as with a plain milling cutter; however, the ends can be cut square to the sides by using the side [periphery] of the end mill.)

EXAMPLE:

FIGURE 8

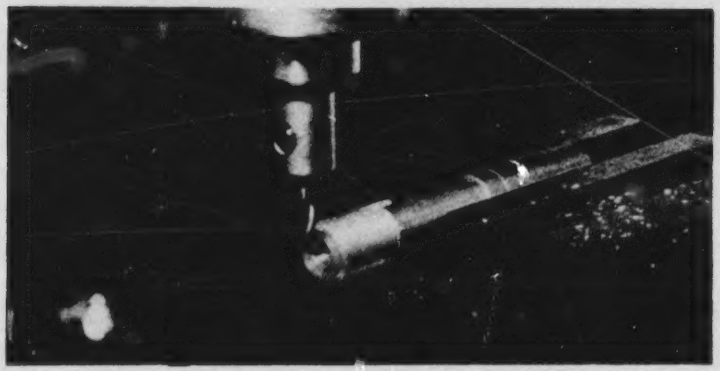


H. Milling key slots and key seats — Cutting slots to receive keys

(NOTE: End mills are used to cut key slots. A keyseat cutter is used to cut key seats.)

EXAMPLE:

FIGURE 9

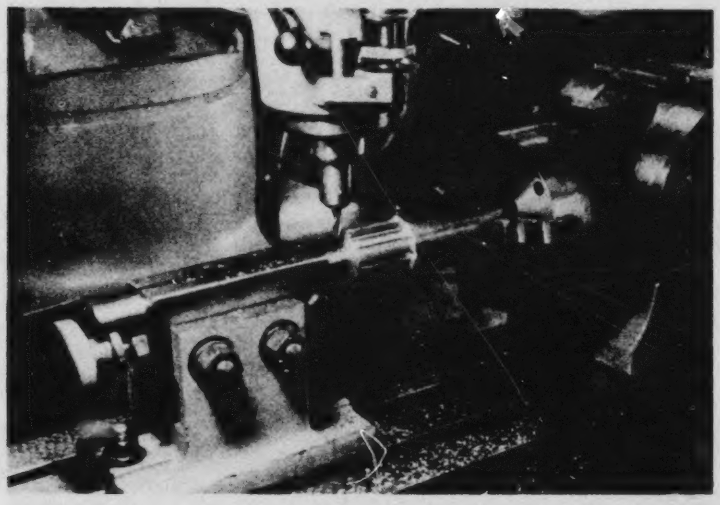


INFORMATION SHEET

I. Indexing — Rotating workpiece a specific fractional amount of a turn to perform repeated milling operations

EXAMPLE:

FIGURE 10

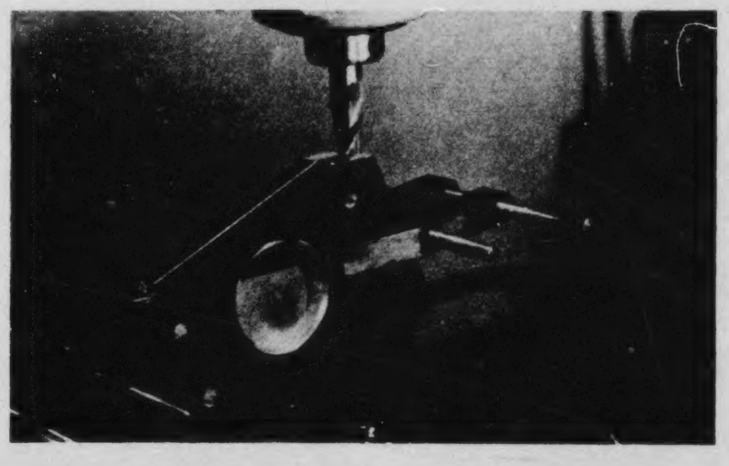


J. Angular milling — Milling an angle on a workpiece with reference to a designated surface

(NOTE: The workpiece may be set at the required angle, or the workhead may be tilted. Either the end or the side of the cutter may be used.)

EXAMPLE:

FIGURE 11

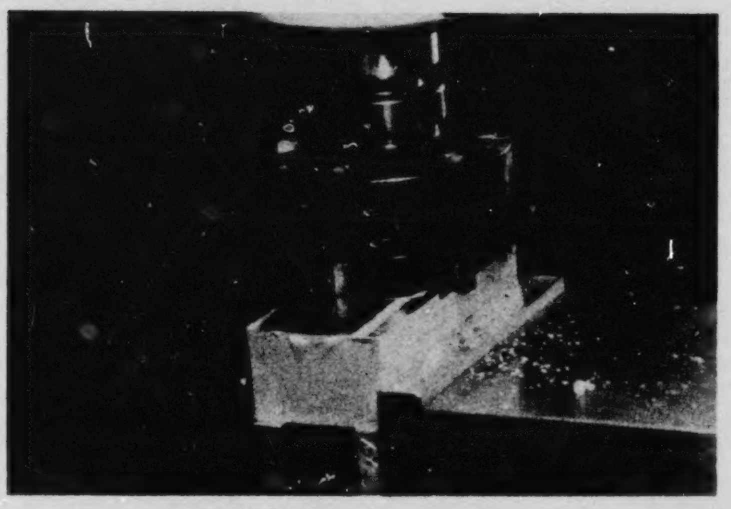


INFORMATION SHEET

K. Fly-cutting — Producing a large flat surface 90 degrees to axis of spindle with cutter or cutters mounted to a holder

EXAMPLE:

FIGURE 12



VERTICAL MILLING MACHINES
UNIT III

ASSIGNMENT SHEET #1 -- LIST REQUIRED MILLING OPERATIONS

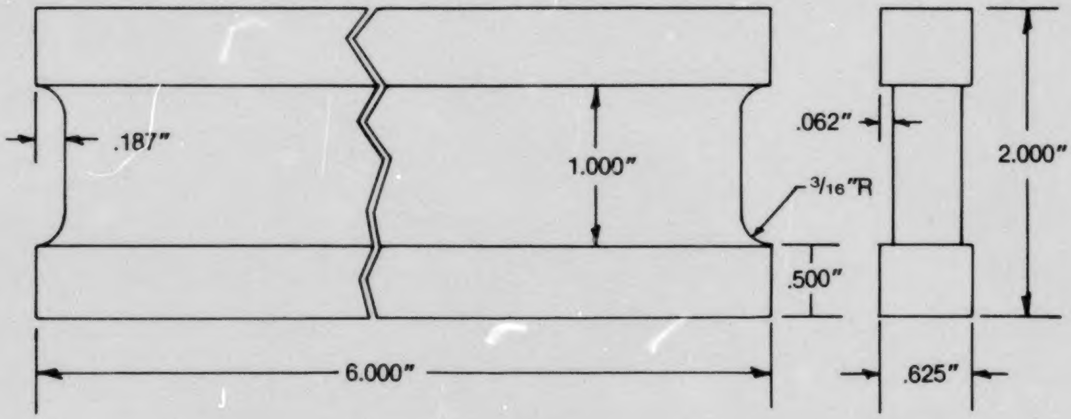
NAME ______________________________ SCORE ______________

The ability to look at a blueprint and determine the various operations helps you plan your machining sequences.

From the following blueprints, list the various operations you must perform to make the part.

A. Material: 2-by-5/8-inch 1055 steel bar

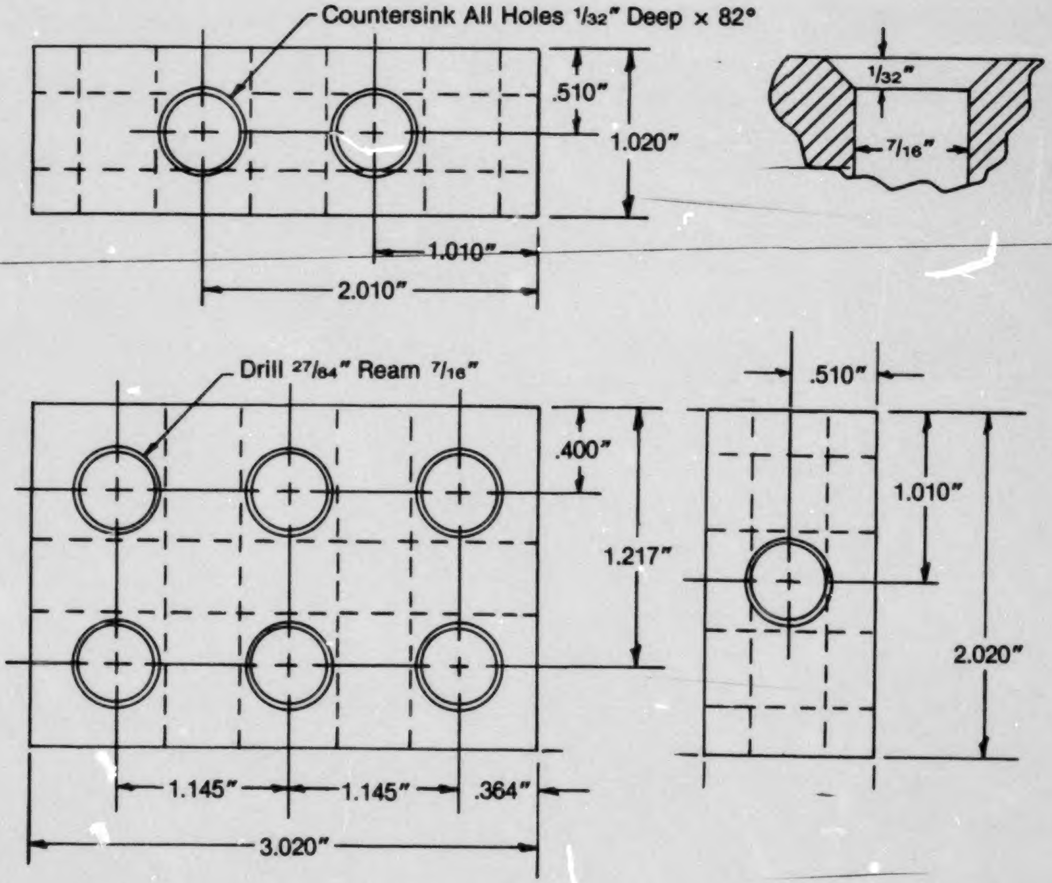
Operation: Rough cut to 6 1/8 inches long



ASSIGNMENT SHEET #1

B. **Material:** 1 1/16-by-2 1/8-inch flat, ground steel bar (A2)

Operation: Cut to 3 3/16 inches long


Countersink All Holes 1/32" Deep × 82°
.510"
1.020"
1.010"
2.010"
1/32"
7/16"
Drill 27/64" Ream 7/16"
.400"
1.217"
1.145"
1.145"
.364"
3.020"
.510"
1.010"
2.020"

ASSIGNMENT SHEET #1

VERTICAL MILLING MACHINES
UNIT III

ANSWERS TO ASSIGNMENT SHEET

A. 1. Side mill to length

2. Mill 3/16-inch recess

3. Mill 1/16-inch recess

B. 1. Cut to 2.020 inches, end mill

2. Cut to 3.020 inches, side mill

3. Cut to 1.020 inches, end mill

4. Center drill; drill and ream

5. Countersink

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #1 — MOUNT AND REMOVE CUTTERS AND CUTTER HOLDERS FOR VERTICAL SPINDLE MACHINES

I. Equipment and materials

- A. Vertical mill with end mill holders and collets
- B. Wrenches to fit drawbar and end mill holder
- C. Soft-faced mallet
- D. Clean shop rag
- E. End mill to fit collet or holder

II. Procedure

- A. Mount collet and end mill in spindle
  1. Clean collet with rag
  2. Clean spindle with rag
  3. Locate spindle with key
  4. Insert collet in spindle, with slot aligned with key, and hold with one hand; turn head of drawbar with other hand until drawbar threads will hold collet
  5. Clean shank of end mill
  6. Insert end mill in collet until about 1/4 inch of shank portion is visible; hand-tighten drawbar

     (CAUTION: Use rag when holding end mill to prevent cutting your hands.)
  7. Place wrench on drawbar nut
  8. Hold spindle brake with left hand and tighten drawbar

     (CAUTION: Remove wrench from drawbar.)
- B. Remove collet and end mill
  1. Place wrench on drawbar head and hold brake
  2. Loosen drawbar about one revolution

JOB SHEET #1

3. Use rag to hold end mill with one hand; strike head of drawbar with mallet

   (NOTE: This action breaks the collet from the tapered portion and allows the collet to spring open.)

   (CAUTION: Always hold end mill to prevent it from falling out of the collet and damaging workpiece or chipping cutter. Never loosen drawbar all the way because the impact of breaking the taper will damage drawbar and collet threads.)

4. Remove end drill

5. Remove collet

   (NOTE: The same basic technique is used when removing drill chuck or other attachments from spindle.)

C. Mount end mill holder and end mill in spindle

   1. Clean end mill holder with rag

   2. Clean spindle with rag

   3. Locate spindle key

   4. Insert holder in spindle with slot aligned with key

   5. Support holder in spindle with one hand; tighten drawbar with other hand until threads of drawbar secure holder

   6. Place wrench on drawbar nut

   7. Hold spindle brake with left hand and tighten drawbar

      (NOTE: Brake will not work if spindle is in neutral.)

   8. Clean shank of end mill, and insert it into end mill holder so that flat surface on shank is in same position as end mill holder setscrew

   9. Slide shank in holder until setscrew seats on the flat; tighten setscrew

D. Remove end mill and end mill holder

   1. Hold end mill with rag; loosen setscrew on end mill holder until end mill can be removed

   2. Remove end mill and store in safe place

JOB SHEET #1

3. Use wrench to loosen drawbar one revolution
4. Strike head with mallet to break taper
5. Unscrew drawbar with one hand while supporting holder with the other hand until end mill holder is free
6. Remove drawbar and place on bench or put in holder and store in safe place

E. Clean and put away all tools and equipment

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #2 — USE MACHINE CONTROLS PROPERLY

I. Equipment and materials

A. Vertical mill with power feed

B. Operator's manual for vertical mill

II. Procedures

(NOTE: These procedures will not apply to all milling machines. Refer to Transparency #3 in Unit I and to operator's manual for the particular machine being used.)

A. Set spindle speeds

1. Move high/neutral/low selector switch to high-range position, and rotate spindle by hand until direct drive pin locks in position

   (CAUTION: Do not shift high/neutral/low selector switch while spindle is rotating by power. Never turn spindle power on until the direct drive plate has engaged.)

2. Move forward/reverse switch to forward position

3. Start spindle

4. Crank speed change handwheel until 1,500 appears in high window on variable speed dial

   (CAUTION: Never turn speed change handwheel unless spindle power is on.)

5. Stop machine

6. Move high/neutral/low selector switch to low position, and turn spindle by hand until direct drive pin locks

7. Start spindle

8. Adjust speed change handwheel to 100 revolutions per minute (rpm)

9. Stop spindle

10. Repeat steps 1 through 5 as necessary to set the machine to operate at 1,000 rpm

JOB SHEET #2

B. Engage power quill feed and set quill stop

1. Engage power-feed transmission

   (NOTE: Engagement of transmission may be done at any time.)

   (CAUTION: Power quill feed should not be used when spindle speed is above 3,000.)

2. Move quill feed selector to a middle-range position

   EXAMPLE: Certain Bridgeport models have three quill feed positions: 1½ (0.0015 inch), 3 (0.003 inch), and 6 (0.006 inch). For this type of machine, set the quill feed selector at 3.

3. Loosen quill lock

4. Pull quill feed handle down to the 1-inch mark

5. Adjust micrometer adjusting nut to the 2-inch mark; lock in place with locknut

   (CAUTION: Never operate power feed with quill lock tightened.)

6. Set feed reverse knob for downfeed; push or pull knob until clutch engages and housing behind knob begins rotating

   (NOTE: Direction of feed depends on rotation of spindle. To obtain downfeed when spindle is rotating clockwise, the knob is pulled out; if spindle is rotating counterclockwise, the knob is pushed in.)

7. Pull feed control lever out to engage power feed of quill

8. Allow quill to feed down until quill stop makes contact with micrometer adjusting nut

   (NOTE: When contact is made, the feed control lever will kick in, disengaging the quill feed.)

9. Manually return quill to the 1-inch mark

   (NOTE: To feed the quill up into the spindle, the feed reversing knob must be pushed in; however, the feed will not stop until the spindle reaches its home position or the feed lever is pushed in.)

JOB SHEET #2

C. Manual table feed controls

(NOTE: Before moving any of the handcranks, always check table locks to make sure that the locks are in the unlocked position.)

1. Move table to right with one of the longitudinal-feed handcranks
2. Engage table lock
3. Turn longitudinal-feed handcrank right and then left until you feel the table start to move

   (NOTE: Do not try to force the handcrank. Practice this procedure to get a feel for these controls. The free movement of the table is called *backlash*.)

D. Manual cross-feed controls

1. Pull saddle locking lever up to loosen it
2. Move table in three complete turns of the cross-feed handcrank
3. Push saddle locking lever down
4. Turn cross-feed handcrank to get a feel for the backlash in the cross-feed screw

E. Manual elevating feed controls

1. Push knee clamping lever down to loosen it
2. Turn elevating handcrank clockwise six revolutions to raise table
3. Turn elevating handcrank counterclockwise three revolutions to lower table

   (NOTE: Because the weight of the table and knee rests on the elevating screw, there is no noticeable backlash.)

4. Pull knee clamping lever up to lock knee in place

F. Longitudinal power feed

1. Turn on main power switch

   (NOTE: Most machines have a light to show that power is on.)

2. Turn feed rate control knob to 4 inches per minute (ipm)

JOB SHEET #2

3. Adjust right and left trip dogs to 8 inches each side of feed stop
4. Engage power-feed engagement lever to move table to right
5. Allow table to move until trip dogs make contact with stop; then disengage power feed
6. Pull feed engagement lever to left
7. Increase feed to 10 ipm for about one minute

   (NOTE: The rate of feed can be changed while the table is moving.)
8. Set feed to 1 ipm
9. Push in the rapid-travel button

   (NOTE: The rapid-travel button overrides the setting of the feed dial.)
10. Release rapid-travel button as table nears left trip dog

G. Turn off power, and place all levers in neutral or locked positions

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #3 — MOUNT AND ALIGN VISE

I. Equipment and materials

A. Vertical milling machine

B. Vise with swivel base

C. Plunger-back dial indicator set

D. Drill chuck and chuck key

E. Wrenches to fit drawbar, vise, and T-bolts

F. Clean rag

G. Long-angle lathe file (14 inches) with handle

H. T-bolts with flange nuts

II. Procedure

A. Clean table with rag

B. Run hand over surface of table in area where vise is to be mounted to check for burrs

1. If burrs are detected, use file flat on surface of table to file off burrs

2. Wipe off filings and recheck for burrs

3. Continue this process until table is clean and free of burrs

C. Place vise on bench with base up

D. Clean bottom of vise with rag

E. Check for burrs; remove burrs if necessary

F. Set vise on table so that jaws of vise are parallel to T-slots,and locating lugs are in center of table in center T-slot

G. Insert T-bolts in center T-slot; slide to cutouts in vise base

(NOTE: Some vises have holes instead of slots. These require that the T-bolts be placed in the table slots and aligned with the holes in the vise. The vise is then placed over the bolts.)

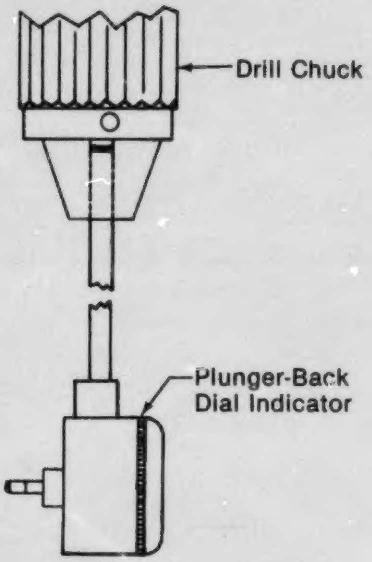
JOB SHEET #3

H. Screw on flange nuts and secure vise to table

I. Mount drill chuck in spindle of mill

J. Mount dial indicator in drill chuck (Figure 13)

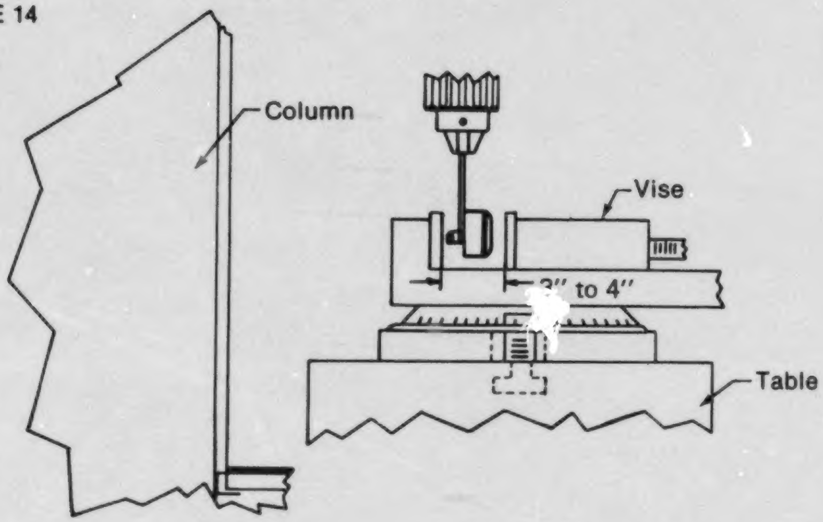
FIGURE 13


Drill Chuck
Plunger-Back Dial Indicator

K. Crank table cross feed to position indicator outside opening of vise jaws, but aligned between jaws

L. With spindle completely in quill, crank table up or down so that indicator can move between vise jaws without touching vise (Figure 14)

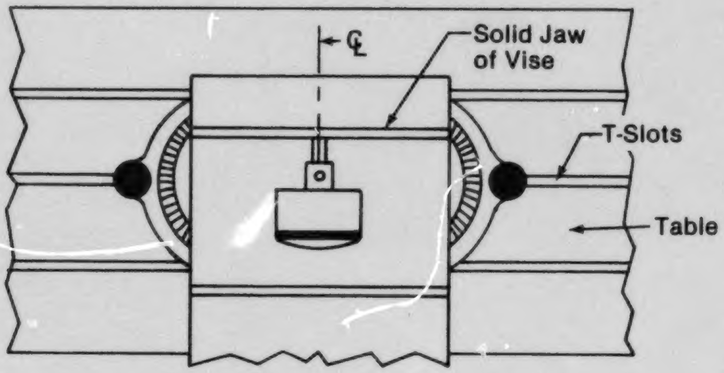
FIGURE 14


Column
Vise
3" to 4"
Table

JOB SHEET #3

M. Center indicator between jaws, using longitudinal and cross-feed handcranks (Figure 15)

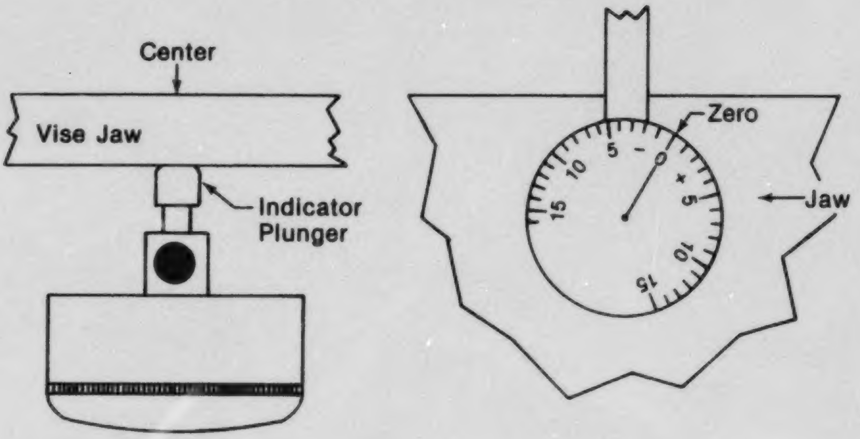
FIGURE 15


℄
Solid Jaw of Vise
T-Slots
Table

N. Rotate indicator as necessary to square indicator plunger with solid jaw of vise

O. Turn cross-travel handcrank counterclockwise to bring solid jaw to indicator; continue to crank until indicator has about a 0.020-inch load (Figure 16)

FIGURE 16


Center
Vise Jaw
Indicator Plunger
Zero
Jaw
15
10
5
–
0
+
5
10
15

JOB SHEET #3

P. Zero dial indicator

Q. Crank longitudinal-feed handcrank to move vise so that indicator reading increases (positive numbers)

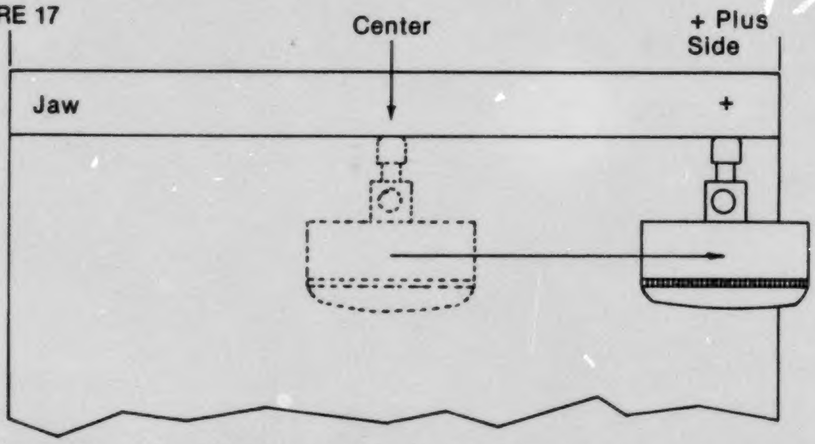
(NOTE: The increased reading indicates that that end of the jaw is closer to the plane of the indicator than the other end.)

R. Continue to move table until indicator is about 1/4 inch from end of jaw

(CAUTION: Do not crank the table so far that the indicator plunger is off the solid jaw.)

S. Note reading (Figure 17)

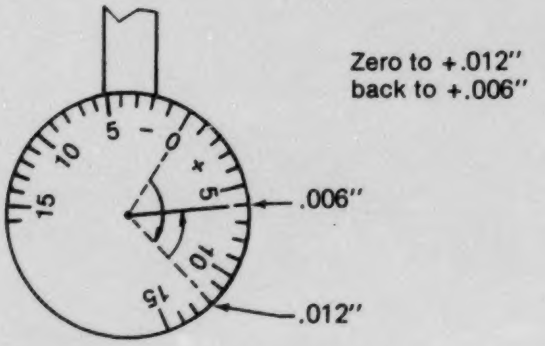
FIGURE 17



T. Tap side of vise with soft mallet until needle has moved toward zero one-half of the reading (Figure 18)

(CAUTION: Tap vise so that the jaw moves away from the indicator, never toward it.)

FIGURE 18



JOB SHEET #3

U. Move indicator back to center of jaw

V. Zero indicator and move it back to end of jaw where adjustment was made

   1. If reading is zero, continue to step W
   2. If reading is a positive number, repeat steps S through V until zero reading is obtained
   3. If reading is a negative number, move indicator to opposite end of jaw and repeat steps S through V for that end until zero reading is obtained

W. Tighten nuts that secure vise to swivel base by snugging right, then left; continue until nuts are tight

X. Check alignment of vise jaw one more time to make sure that vise did not move while you were tightening base

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #4 — ALIGN HEAD SQUARE TO TABLE

I. Equipment and materials

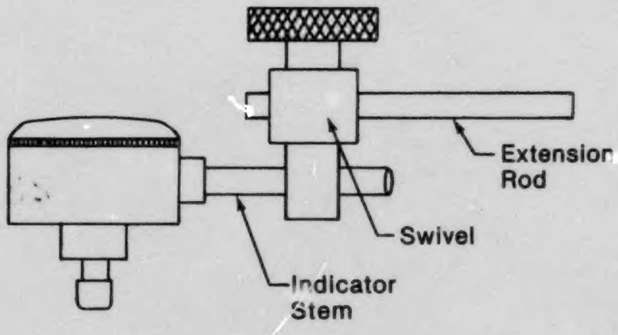
- A. Vertical milling machine
- B. Plunger-back dial indicator set
- C. Clean rag
- D. Drill chuck with arbor to fit spindle
- E. Wrench for drawbar
- F. Torque wrench to fit head adjusting bolts
- G. Plastic card

II. Procedure

- A. Clean off center of machine table with rag
- B. Mount drill chuck in spindle and secure
- C. Place swivel on indicator stem; place extension rod in swivel, tighten lockscrew (Figure 19)

  (NOTE: A dial test indicator can be used; however, it should sweep a circle slightly smaller than the width of the table.)

FIGURE 19



JOB SHEET #4

D. Place spindle in neutral position so that it will rotate freely

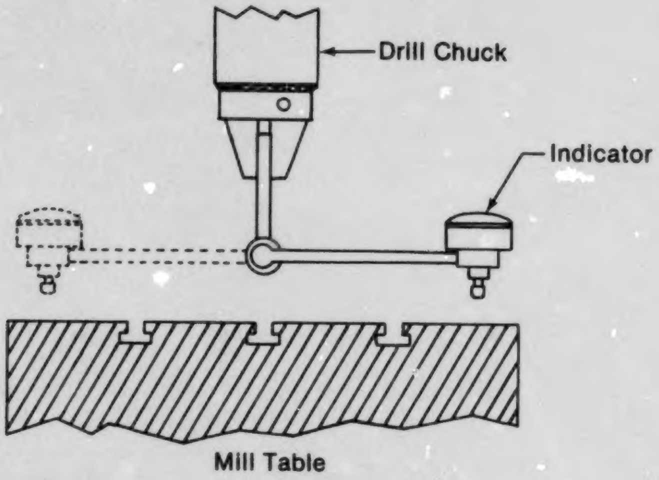
E. Position table feeds so that spindle is in center of table; then pull quill down about 3 inches and lock in position

F. Mount extension rod in drill chuck, and place swivel on extension rod

G. Mount indicator stem in swivel

H. Adjust indicator and stem so that indicator will generate a circle slightly less than the width of the table (Figure 20)

FIGURE 20



I. Raise table until it makes contact with indicator

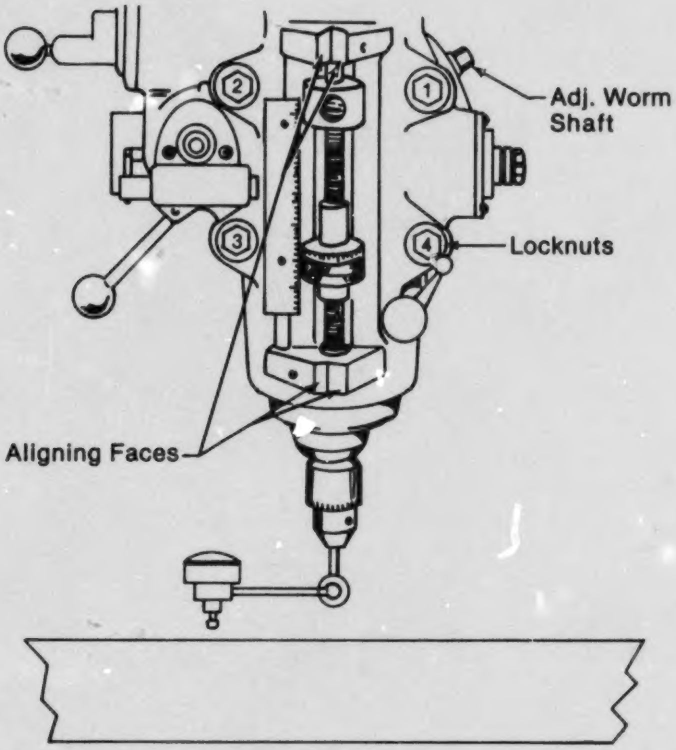
J. Lock all table locks

JOB SHEET #4

K. Align head in *x* axis

1. Loosen locknuts for horizontal adjustment of vertical head; retighten to a snug fit so that there is only slight drag when head is being adjusted (Figure 21)

FIGURE 21



2. Place wrench on adjusting worm shaft, and align zero graduation on zero line

   (NOTE: The zero mark is close; however, for precision machining, you must indicate the head square.)

3. Rotate spindle by hand until indicator is on left side of spindle in center of table

4. Lower quill until contact is made with table; continue lowering quill until indicator reads about 0.015 inch

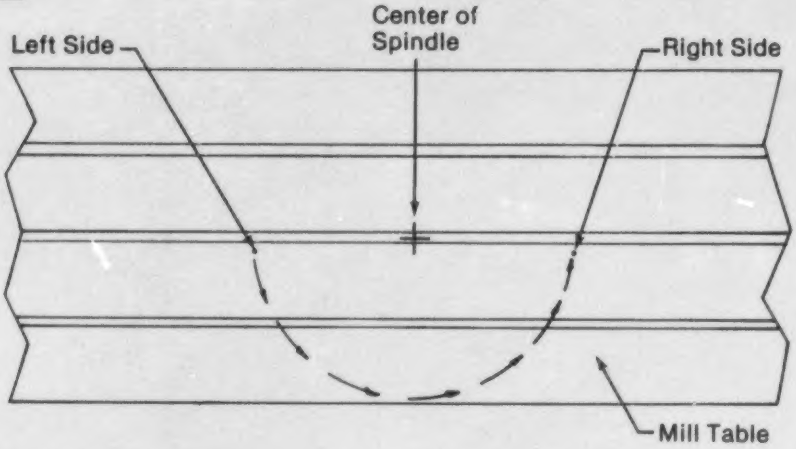
5. Zero indicator

JOB SHEET #4

6. Rotate spindle 180 degrees so that indicator is on right side of spindle (Figure 22)

   (CAUTION: When moving the indicator, use the plastic card to prevent the indictor plunger from dropping down in the T-slot; remove plastic card before making reading.)

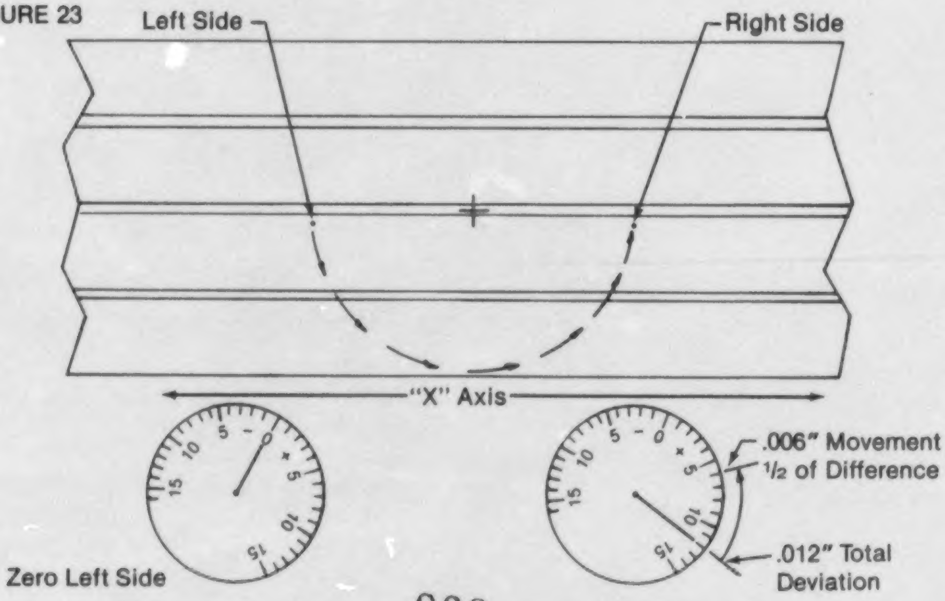
FIGURE 22


Left Side
Center of Spindle
Right Side
Mill Table

7. Note indicator reading

8. Turn adjusting worm shaft to move head until indicator needle moves halfway back to zero (Figure 23)

FIGURE 23


Left Side
Right Side
"X" Axis
15 10 5 – 0 + 5 10 15
Zero Left Side
15 10 5 – 0 + 5 10 15
.006" Movement
1/2 of Difference
.012" Total
Deviation

JOB SHEET #4

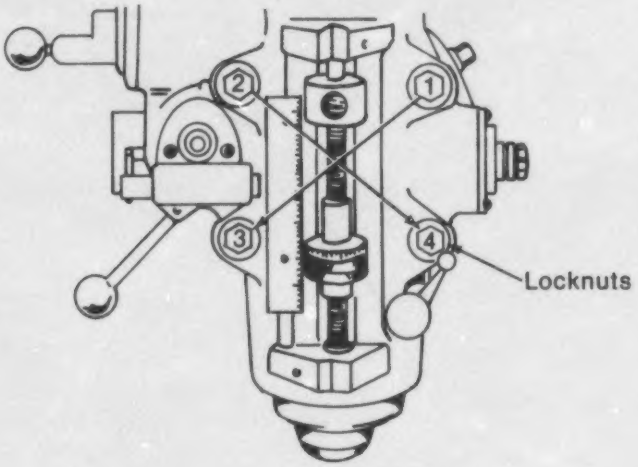
9. Rotate spindle by hand back to left side so that indicator is at original zeroed position

10. Zero indicator

11. Repeat steps 6 through 9 until zero reading is obtained on each side of spindle

12. Tighten securing bolts in X pattern to recommend torque (Figure 24)

FIGURE 24



13. After locknuts are tight, recheck setting to make sure that head did not slip

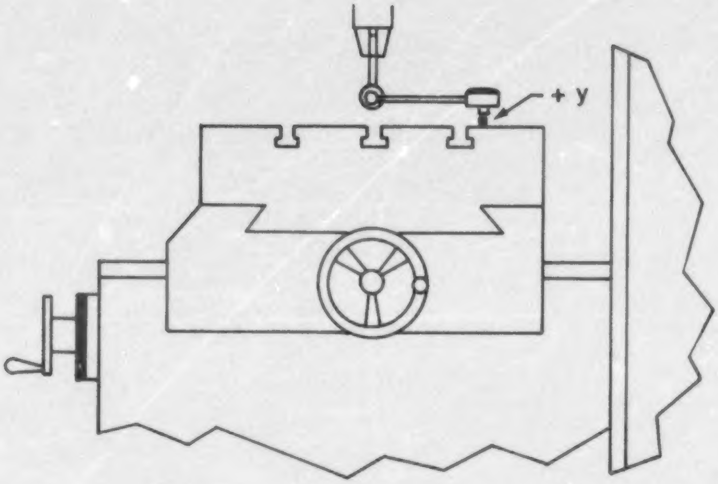
L. Align head in *y* axis

1. Loosen lockbolts for vertical adjustment on vertical head; retighten to a snug fit so that there is only slight drag when head is being adjusted

JOB SHEET #4

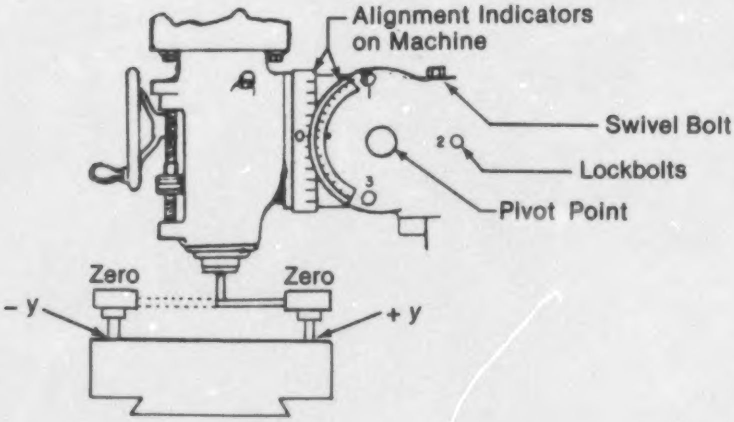
2. Align zero mark with witness line, using vertical adjusting worm shaft (Figure 25)

FIGURE 25



3. Rotate spindle to side of table closest to column (Figure 26)

FIGURE 26


Alignment Indicators on Machine
Swivel Bolt
2
Lockbolts
3
Pivot Point
Zero
Zero
– y
+ y

Head Alignment *y* Axis

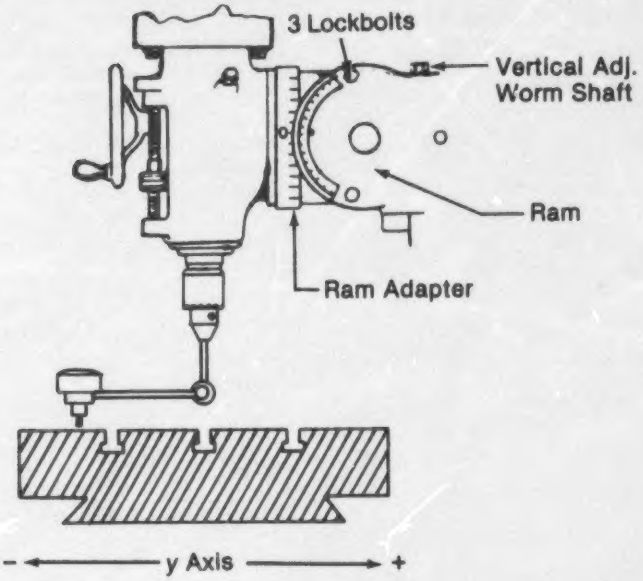
Used with permission of Bridgeport Machines.

JOB SHEET #4

4. Raise or lower quill until indicator reads about 0.015 inch; zero indicator

5. Rotate spindle 180 degrees, moving indicator opposite column (Figure 27)

FIGURE 27


3 Lockbolts
Vertical Adj. Worm Shaft
Ram
Ram Adapter
- y Axis +

Adapted with permission of Bridgeport Machines.

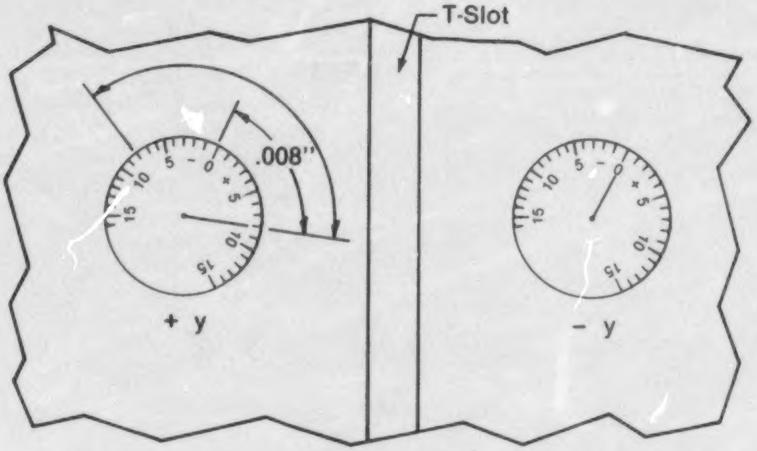
6. Note indicator reading

JOB SHEET #4

7. Adjust head by turning vertical adjusting shaft to move head so that indicator reads zero; continue adjustment until indicator reads the opposite of the first reading (Figure 28)

   (NOTE: If the original reading was +0.008 inch, the adjusted reading should be −0.008 inch for a total movement of 0.016 inch. This will put you close. Many variables in distance from spindle to table enter into the movement of the head.)

FIGURE 28



8. Repeat steps 5 through 7 until zero reading is obtained at both locations

   (NOTE: It may be necessary to leave a reading of about +0.005 inch on the side opposite the column to allow for the torque of tightening the lockbolts.)

9. Tighten lockbolts

M. Rotate spindle in a complete circle around table and check readings; adjust as necessary

N. Have your instructor check your work

   (NOTE: You should be able to perform this procedure in about ten minutes. If it took you longer than ten minutes, continue to practice until you can perform the procedure quickly and efficiently.)

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #5 — PERFORM A SIDE MILLING OPERATION

I. Equipment and materials

- A. Vertical mill with vise and coolant
- B. Four-flute, center-cut end mill, $^5/_8$ inch
- C. Drill chuck
- D. End mill holder or collet, $^5/_8$ inch
- E. Wrenches for vertical head, T-bolts, and end mill holder
- F. Dial indicator set
- G. Clean rag
- H. Matched set parallels
- I. SAE 1055 steel bar, 2" × $^5/_8$" × 6 $^1/_8$"
- J. Four-flute end mill, $^3/_8$ inch
- L. Soft-faced mallet
- M. Vernier calipers, 8 inches

II. Procedure

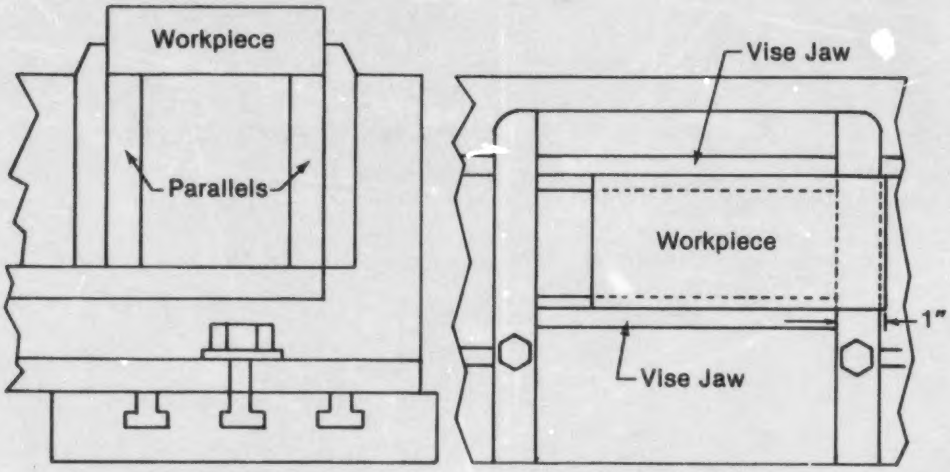
- A. Check oil levels and perform daily maintenance if necessary
- B. Align head square to table
- C. Mount and align vise so that jaws are parallel to T-slots
- D. Insert $^5/_8$-inch end mill holder in spindle and secure; put end mill cutter in holder and secure

  (NOTE: Make sure that the setscrew of the holder seats on the flat of the end mill.)
- E. Clean vise

JOB SHEET #5

F. Set parallels in vise, and place workpiece with 2-inch surface on parallels, the end protruding from right side of vise about 1 inch (Figure 29)

FIGURE 29

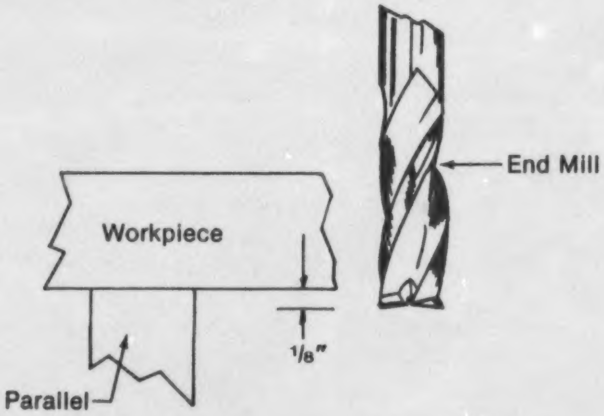

Workpiece
Parallels
Vise Jaw
Workpiece
1"
Vise Jaw

G. Seat work on parallels with mallet

H. Set spindle speed at 544 rpm

I. With quill fully in its housing and locked, crank up table until end of mill is about 1/8 inch below bottom of work surface (Figure 30)

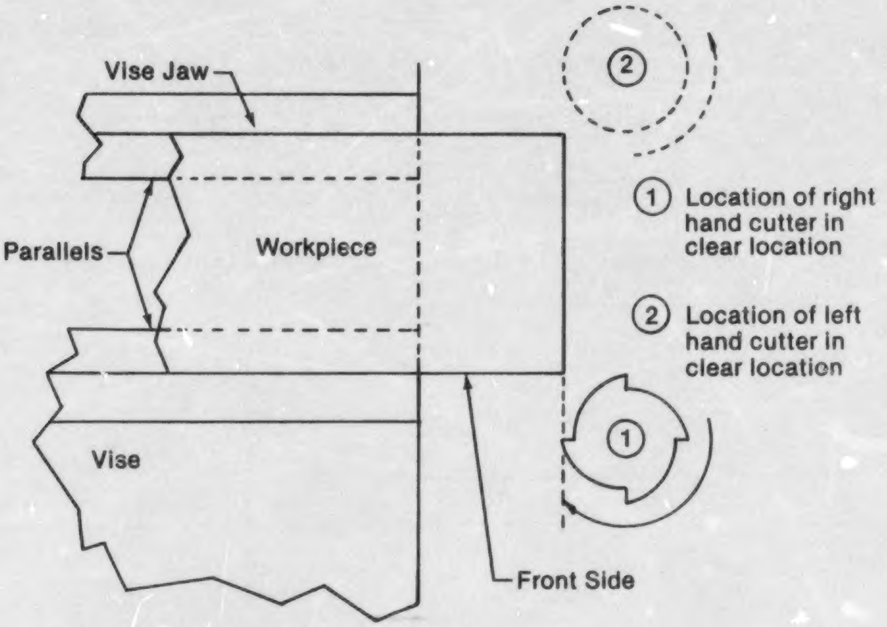
FIGURE 30


End Mill
Workpiece
1/8"
Parallel

JOB SHEET #5

J. Start spindle rotating clockwise, and feed workpiece until end mill just shaves the end (Figure 31)

FIGURE 31


Vise Jaw
Parallels
Workpiece
Vise
Front Side
②
①
① Location of right hand cutter in clear location
② Location of left hand cutter in clear location

K. Move workpiece clear of cutter

L. Set graduated collar at right end of table to zero

M. Crank longitudinal-feed handwheel to move workpiece 0.030 inch toward cutter from point where end mill shaved workpiece

N. Lock longitudinal table feed

O. Start coolant

P. Feed workpiece into cutter by cranking cross-travel handwheel counter-clockwise with a steady, continuous motion until cutter clears opposite side

Q. Crank table back to starting position with same steady motion

(CAUTION: Table should be advanced only when cutter is at starting position.)

R. If saw marks are visible, advance workpiece another 0.030 inch

JOB SHEET #5

S. Lock table and make another cut

T. Continue cutting until end is smooth

U. Stop spindle

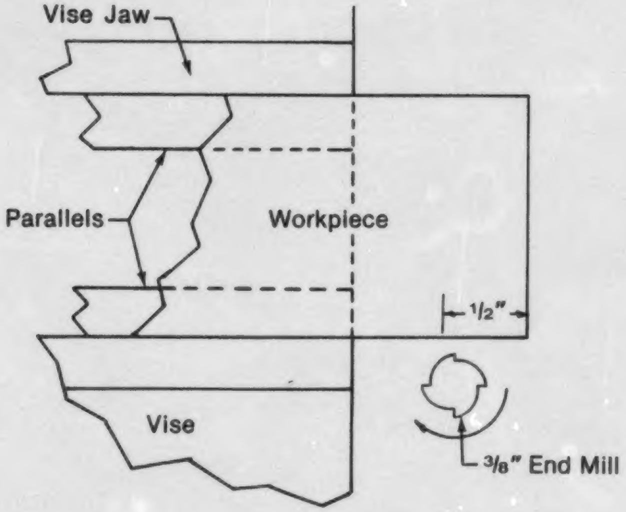
V. Remove 5/8-inch from holder and remove holder

W. Insert 3/8-inch holder and secure 3/8-inch end mill

X. Crank up table until end of end mill is about 1/32 inch below bottom surface of workpiece

Y. Position end mill so that it will clear the front side of workpiece by 1/2 inch (Figure 32)

FIGURE 32

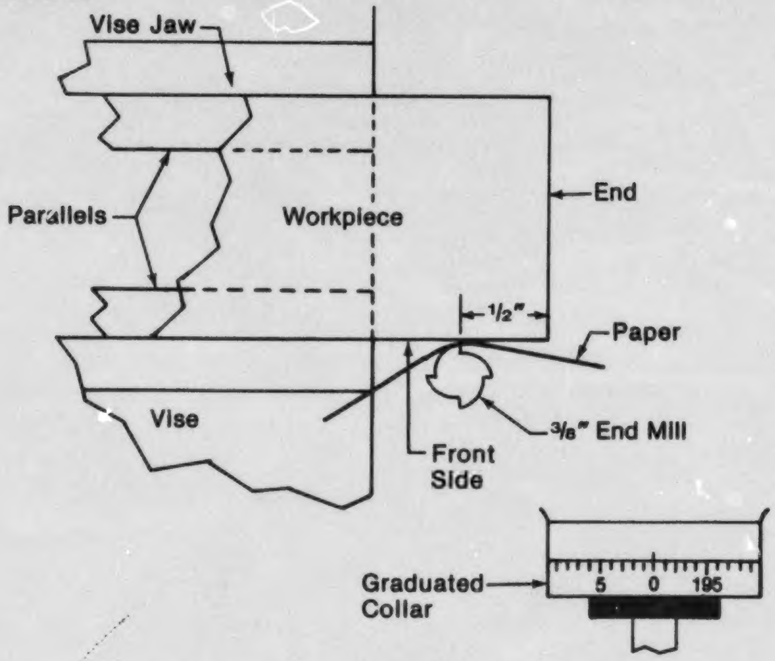

Vise Jaw
Parallels
Workpiece
1/2"
Vise
3/8" End Mill

Z. Set speed at 906 rpm and start spindle

JOB SHEET #5

AA. Hold a piece of paper between workpiece and cutter, and crank cross-travel handwheel counterclockwise until end mill just shaves paper (Figure 33)

FIGURE 33


Vise Jaw
Parallels
Workpiece
End
1/2"
Paper
Vise
3/8" End Mill
Front Side
Graduated Collar
5
0
195

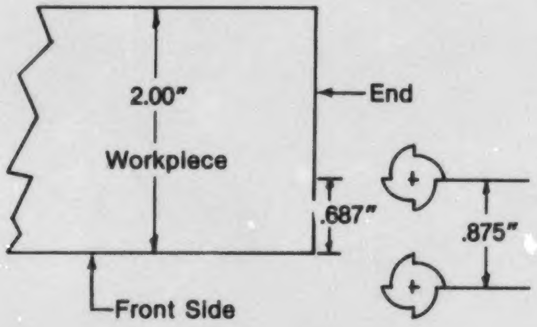
BB. Zero cross-travel handcrank graduated collar

CC. Turn longitudinal-feed handcrank on right side of table clockwise until end mill clears end of workpiece

DD. Crank cross travel counterclockwise 0.875 inch from zero setting; lock saddle (Figure 34)

(NOTE: Numbers on graduated collar will read backwards.)

FIGURE 34

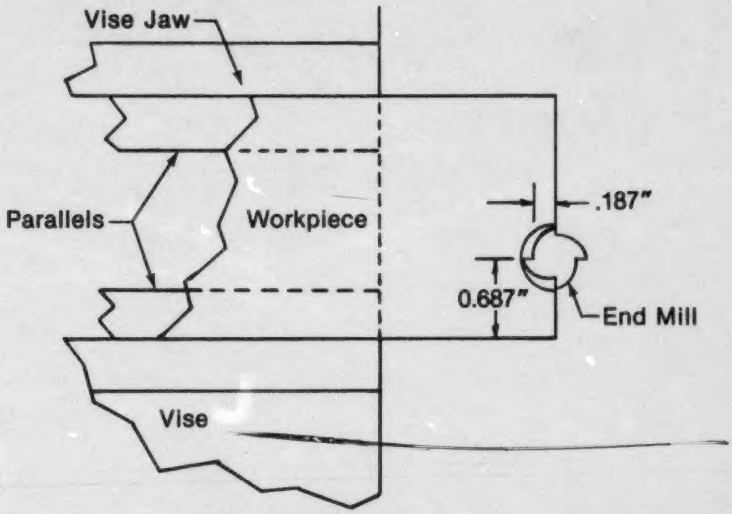

2.00"
Workpiece
End
.687"
.875"
Front Side

JOB SHEET #5

EE. Move workpiece toward cutter until it just shaves workpiece; zero graduated collar of longitudinal feed

FF. Continue to feed end mill another 0.187 inch past end of work; lock table clamp of longitudinal travel (Figure 35)

FIGURE 35

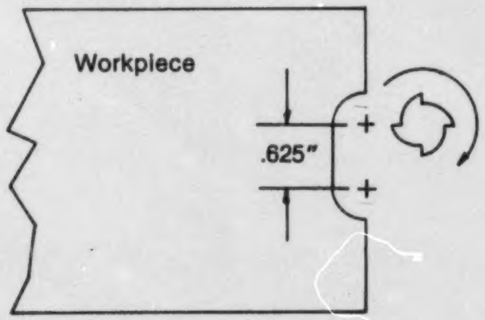

Vise Jaw
Parallels
Workpiece
.187"
0.687"
End Mill
Vise

GG. Unlock saddle and move cross-travel handcrank counterclockwise to feed workpiece another 0.625 inch

HH. Unlock longitudinal clamp and move cutter out of workpiece (Figure 36)

(NOTE: The end mill cutters have been cutting with the conventional method [feeding work against rotation of cutter].)

FIGURE 36


Workpiece
.625"

JOB SHEET #5

II. Stop spindle; remove cutter and holder

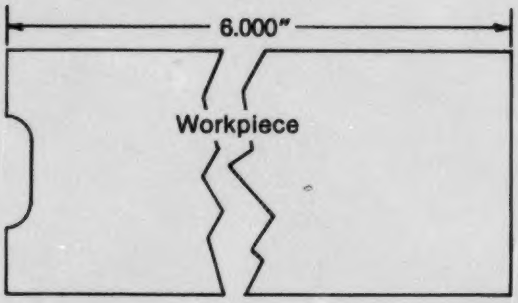
JJ. Remove workpiece from vise and turn end over end

KK. Put ⁵/₈-inch holder and mill in spindle; cut end smooth

LL. Measure workpiece with vernier calipers

MM. Continue cuts of 0.050 inch or less per cut until workpiece is 6 inches long (Figure 37)

FIGURE 37



NN. Change to ³/₈-inch cutter, and cut recesses in ends of both parts

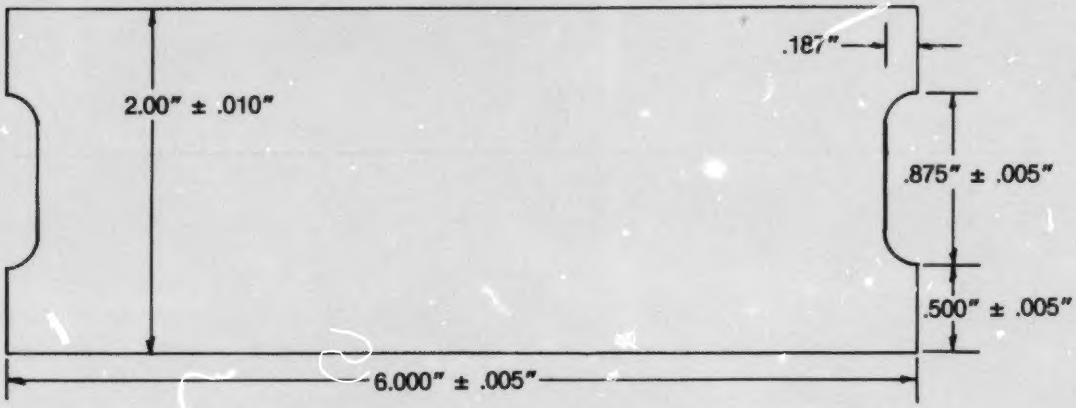
OO. Remove workpiece, and mark it

PP. Deburr workpiece; turn in workpiece to instructor for evaluation

QQ. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

EVALUATION SHEET
JOB SHEET #5


.187"
2.00" ± .010"
.875" ± .005"
.500" ± .005"
6.000" ± .005"

	End A		End B	
	In Tolerance	Out of Tolerance	In Tolerance	Out of Tolerance
Length 6.00 ± .005"				
Squareness 90° ± 30 min				
.500 Length ± .005"				
.875 Length ± .005"				
.187 Depth ± .005"				

Instructor's comments ____

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VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #6 — PERFORM AN END MILLING OPERATION

I. Equipment and materials

- A. Vertical mill with vise and coolant
- B. Two-flute end mill and end mill holder, ¾ inch
- C. Aluminum plate (SAE 2024T4), 4″ × 4″ × ½″
- D. Dial indicator
- E. Clean rag
- F. Vernier calipers, 6 inches
- G. File
- H. Wrenches for drawbar, vise, and end mill holder
- I. Soft-faced mallet

II. Procedures

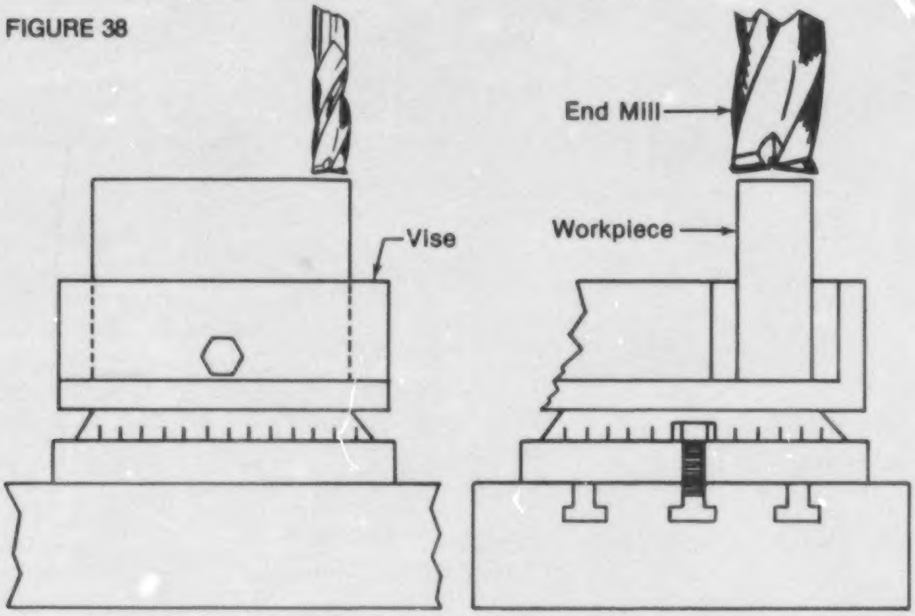
- A. Perform daily maintenance procedures
- B. Align head square to table
- C. Align vise parallel to T-slots
- D. Mount holder in spindle and secure end mill
- E. Set workpiece in vise and secure
- F. Set spindle speed at 1,333 rpm

JOB SHEET #6

G. Center end mill over workpiece (Figure 38)

(NOTE: Quill should be fully retracted in housing and locked.)

FIGURE 38



H. Start spindle

I. Raise table until cutter starts to cut surface; zero elevating graduated collar

J. Clear cutter at right end of workpiece

K. Raise table 0.100 inch

L. Turn on and adjust coolant

M. Crank table from left side by turning handcrank clockwise at about 7.9 inches of feed per minute

N. Continue to feed until cutter is on left side

O. Raise table 0.025 inch; feed cutter back to starting point, and stop spindle

P. Remove and deburr workpiece

Q. Place workpiece cut side down on bottom of vise; tighten vise; seat workpiece

R. Start spindle

JOB SHEET #6

S. Raise table 0.075 inch, and make cut

T. Stop spindle, and measure workpiece with calipers

U. Continue cutting until workpiece measures 3.750 inches

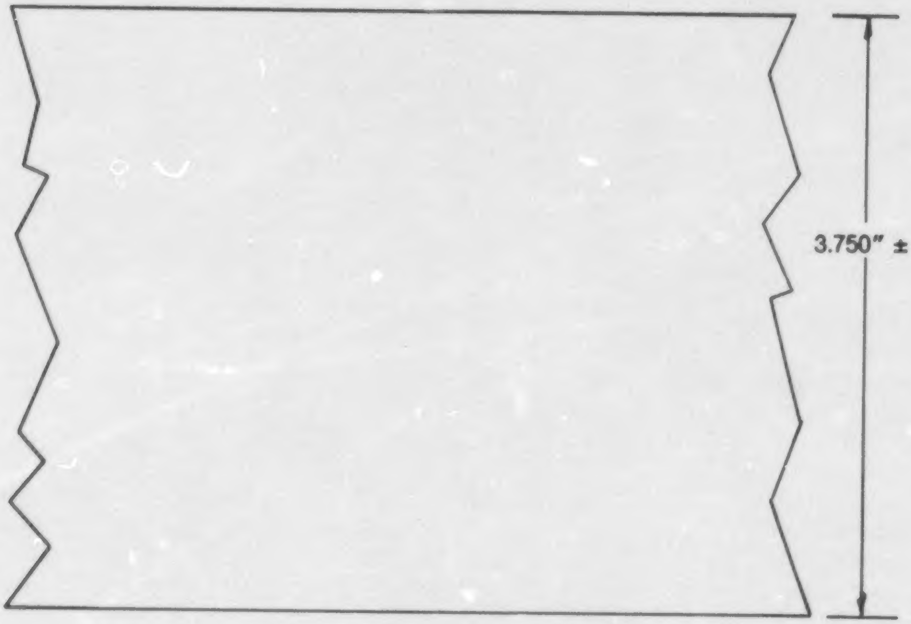
V. Stop spindle, and remove workpiece

W. Deburr workpiece; turn in workpiece to instructor for evaluation

X. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

EVALUATION SHEET
JOB SHEET #6



	In Tolerance	Out of Tolerance
3.750" ± 0.001"		

Instructor's comments ______________________________

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #7 — MILL A KEY SEAT WITH KEYSEAT CUTTER AND A KEY SLOT WITH END MILL

I. Equipment and materials

- A. Vertical mill with vise and coolant
- B. Dial indicator
- C. Manufacturer's #11 Woodruff keyseat cutter (number 607)
- D. Clean rag
- E. Round SAE 1018 steel, 1¼-by-8-inches long with end faced smooth and chamfered
- F. End mill holder, ½ inch
- G. Two-flute end mill, ¼ inch
- H. File
- I. Soft-faced mallet

II. Procedure

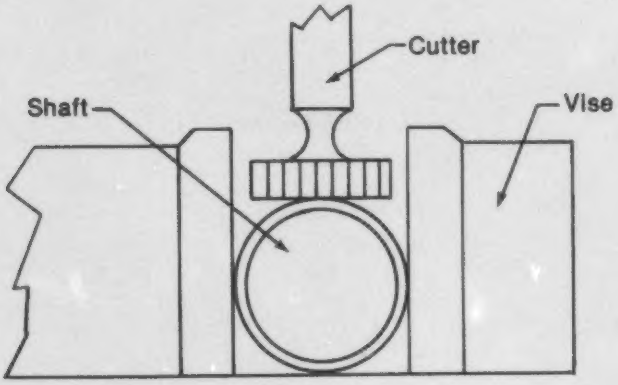
- A. Perform daily maintenance procedures
- B. Align head square to table
- C. Align vise parallel to T-slots
- D. Mount end mill holder in spindle, and secure keyseat cutter in holder
- E. Set workpiece in vise with 2 inches extending past end of jaw on right side of vise

  (NOTE: Faced end should be out of vise.)
- F. With quill fully retracted in housing, start spindle revolving at 125 rpm
- G. Position cutter over workpiece

JOB SHEET #7

H. Raise table until bottom of cutter makes contact with top of workpiece; zero elevating graduated collar (Figure 39)

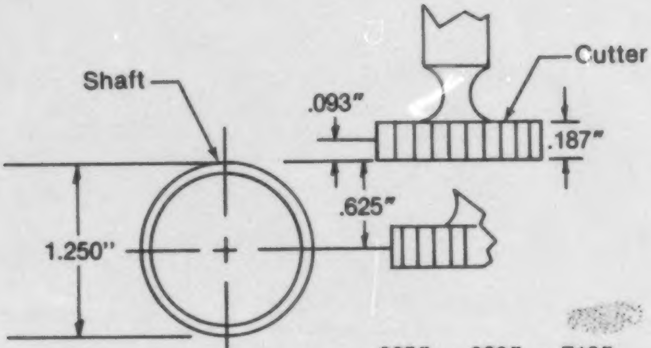
FIGURE 39



I. Move workpiece clear of cutter

J. Raise table a distance equal to one-half the diameter of workpiece plus one-half the thickness of cutter (Figure 40)

FIGURE 40



.625" + .093" = .718"

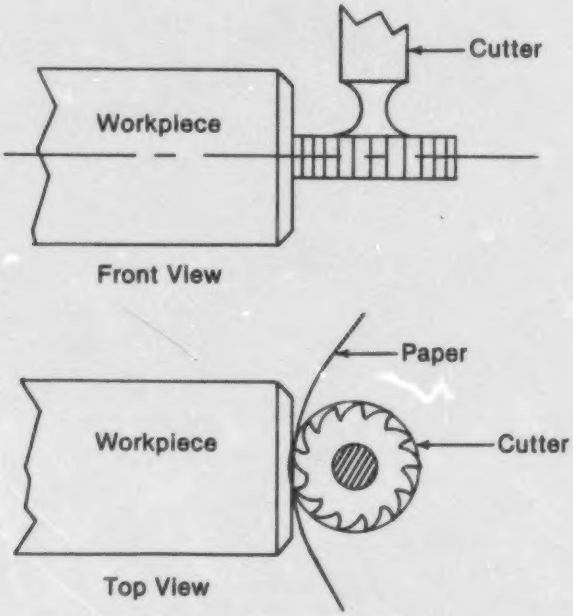
K. Move table feeds so that cutter is positioned near end of workpiece

L. Place strip of paper between end of bar and cutter

JOB SHEET #7

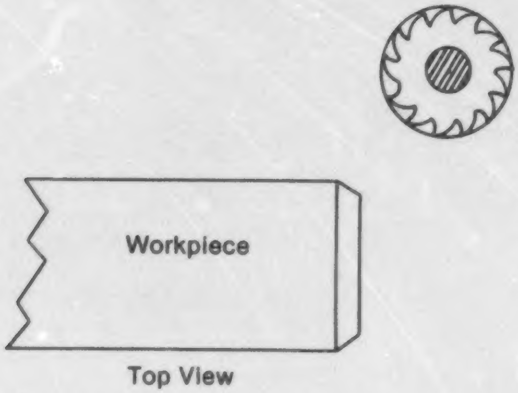
M. Crank longitudinal feed until cutter just shaves paper; zero longitudinal graduated collar (Figure 41)

FIGURE 41


Cutter
Workpiece
Front View
Paper
Workpiece
Cutter
Top View

N. Clear workpiece by turning cross-travel handcrank counterclockwise to move workpiece toward you (Figure 42)

FIGURE 42

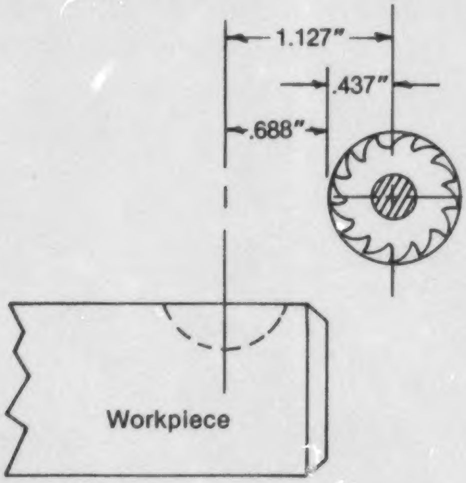

Workpiece
Top View

JOB SHEET #7

O. Turn longitudinal-feed handcrank to move workpiece 1.127 inches: distance from center of keyseat cutter to end of the workpiece, plus one-half diameter of cutter, plus thickness of paper (Figure 43)

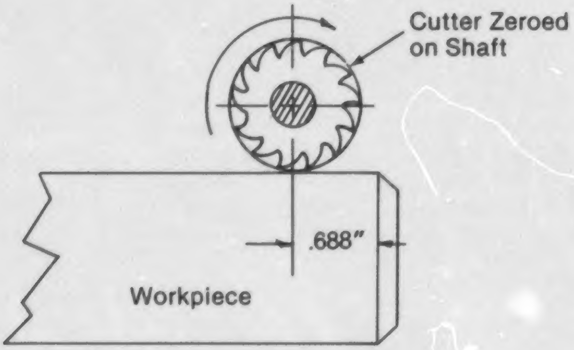
(NOTE: Add thickness of paper to 1.125-inch distance. If paper is 0.002 inch thick, the movement is 1.127 inches.)

FIGURE 43


1.127"
.437"
.688"
Workpiece

P. Turn cross-travel handcrank until cutter starts to shave workpiece; zero graduated collar (Figure 44)

FIGURE 44

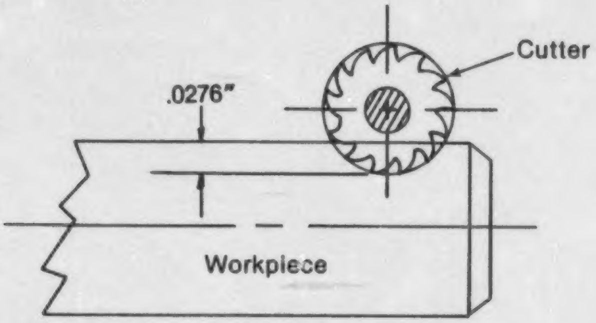

Cutter Zeroed on Shaft
.688"
Workpiece

JOB SHEET #7

Q. Start and adjust coolant; tighten longitudinal table lock; crank in table to cut key seat (Figure 45)

(NOTE: Depths of keyways and key slots vary with the size and type of key. These dimensions should be obtained from a machinery handbook.)

FIGURE 45



R. Clear cutter from workpiece, and stop spindle

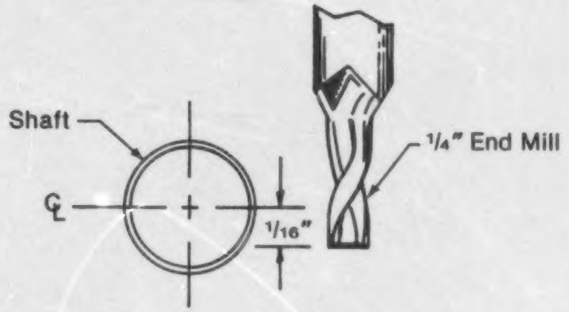
S. Remove cutter and holder

T. Place the ¼-inch end mill in end mill holder, and secure holder in spindle

U. Set spindle speed at 1,360 rpm, and start spindle

V. Make sure that end mill is to one side of workpiece, and raise table until end of cutter is below center of workpiece (Figure 46)

FIGURE 46



W. Place a strip of paper between workpiece and cutter

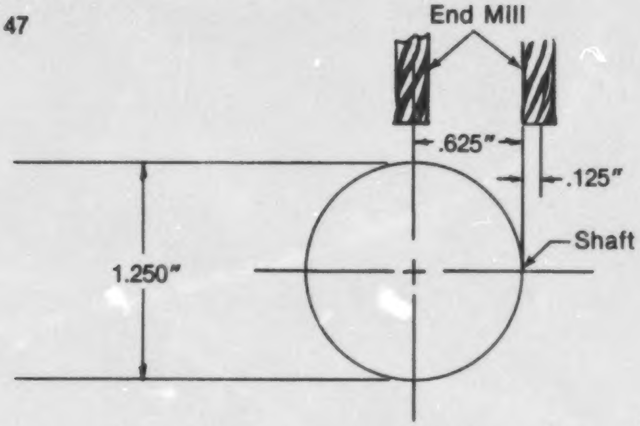
X. Crank cross-travel handcrank to move workpiece toward cutter until cutter starts to shave paper

Y. Lower table so that end of cutter clears top of workpiece; zero graduated collar of cross-travel handcrank

JOB SHEET #7

Z. Center end mill by cranking cross-travel handcrank to move workpiece a distance equal to one-half diameter of workpiece plus one-half diameter of cutter and thickness of paper (Figure 47)

FIGURE 47

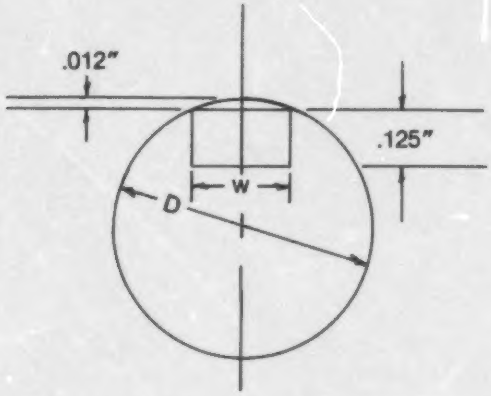


AA. Lock cross-travel feed, and raise table until cutter just shaves workpiece

BB. Zero handcrank elevating graduated collar, and move table to clear workpiece

CC. Raise table 0.137 inch, and turn longitudinal-feed handcrank until cutter shaves end of shaft; zero longitudinal graduated collar (Figure 48)

FIGURE 48



DD. Turn longitudinal-feed handcrank to move workpiece 2.125 inches

EE. Lower table, and clear cutter

JOB SHEET #7

FF. Stop spindle, and remove workpiece

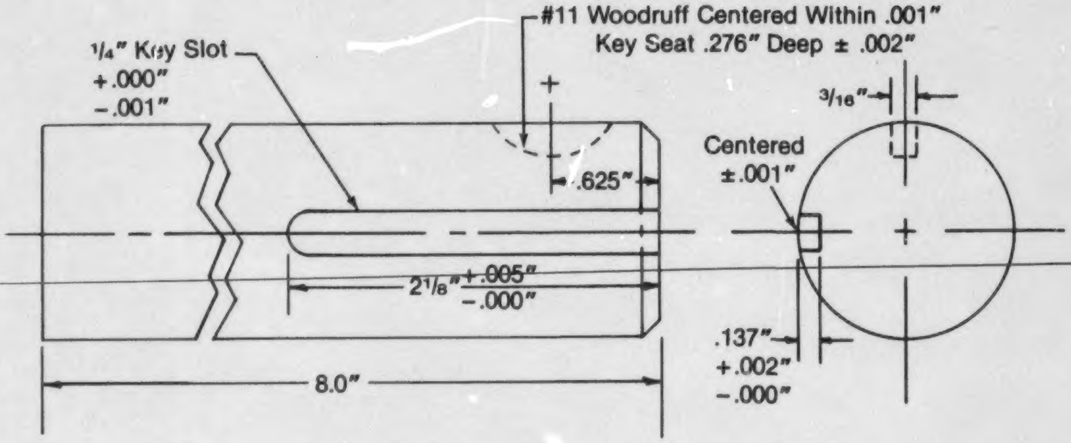
(NOTE: If cutter is left in key slot and allowed to feed out of slot, the key slot will be wider than 0.250 inch.)

GG. Deburr workpiece; turn in workpiece to instructor for evaluation

HH. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

EVALUATION SHEET
JOB SHEET #7



#11 Woodruff Centered Within .001"
Key Seat .276" Deep ± .002"
1/4" Key Slot
+.000"
-.001"
3/16"
Centered
±.001"
.625"
2 1/8" +.005" -.000"
8.0"
.137"
+.002"
-.000"

	In Tolerance	Out of Tolerance
Location Key Seat 5/8		
Location Key Seat Center		
Width of Key Slot		
Length of Key Slot		
Center Location		
Depth of Key Seat		
Depth of Key Slot		

Instructor's comments ____

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VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #8 — MILL A RECTANGULAR POCKET

I. Equipment and materials

- A. Vertical mill with coolant
- B. Two-flute end mill, ¾ inch
- C. End mill holder, ¾ inch
- D. Dial test indicator
- E. Strap clamps, step blocks, stud bolts, T-nuts, and flange nuts to fit machine
- F. Clean rag
- G. Drill chuck with spindle taper to fit mill
- H. Combination square with 12-inch blade
- I. Wrenches to fit drawbar and fastening devices
- J. Premachined aluminum SAE 6061T6 bar, 3" × ⅝" × 7"
- K. Soft-faced mallet
- L. File with handle
- M. Micrometer, 0 inch to 1 inch

II. Procedure

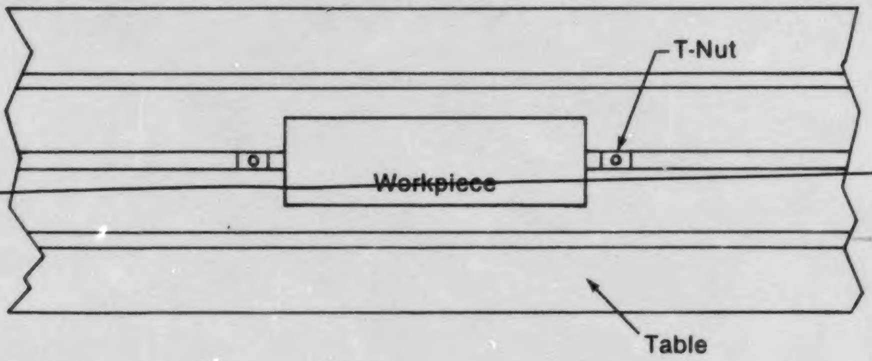
- A. Perform daily maintenance
- B. Align head square to table
- C. Set workpiece on table, centered over center T-slot with 7-inch length parallel to T-slots

JOB SHEET #8

D. Put T-nuts in slots; slide to 1/2 inch from end of workpiece (Figure 49)

(NOTE: Stud bolts should be as close to workpiece as possible.)

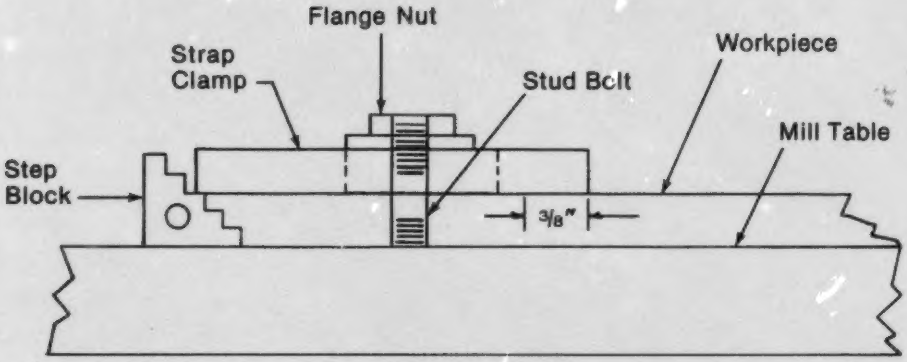
FIGURE 49


T-Nut
Workpiece
Table

E. Screw stud bolts into T-nuts; place strap clamps over bolts

F. Set step block under end of strap clamp so that clamp is parallel to and slightly above 3/8-inch side of workpiece (Figure 50)

FIGURE 50


Flange Nut
Strap Clamp
Stud Bolt
Workpiece
Mill Table
Step Block
3/8"

G. Finger-tighten flange nuts

H. Repeat steps D through G to clamp other end of workpiece

I. Use combination square to rough align workpiece

1. Place combination square head on table

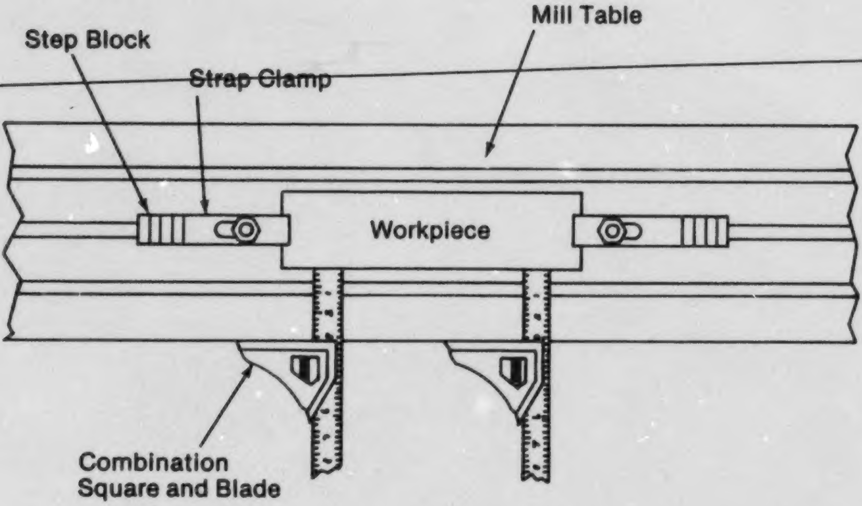
JOB SHEET #8

2. Slide blade out until it touches workpiece

3. Tighten blade locknut

4. Adjust workpiece until it touches combination square blade near each end (Figure 51)

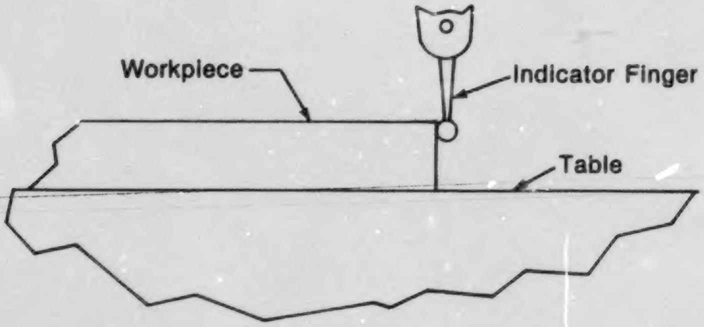
FIGURE 51


Step Block
Mill Table
Strap Clamp
Workpiece
Combination Square and Blade

J. Snug one flange nut

K. Place test indicator in spindle so that plunger indicates along side used for rough alignment (Figure 52)

FIGURE 52


Workpiece
Indicator Finger
Table

JOB SHEET #8

L. Position indicator so that it touches workpiece near end under tightened clamp, with about 0.015-inch load; zero indicator

M. Move indicator to other end; note reading

N. Tap workpiece gently with mallet until needle moves one-half the distance to zero

(CAUTION: Tap workpiece so that it moves away from dial indicator, never toward it.)

O. Move workpiece to place indicator at other end; zero indicator

P. Repeat steps M through O until a zero reading is obtained at each end; tighten clamp bolts and recheck alignment

Q. Remove indicator and drill chuck

R. Insert end mill holder in spindle, and secure end mill cutter in holder

S. With tool clear of workpiece and mill table, lower quill about 1 inch

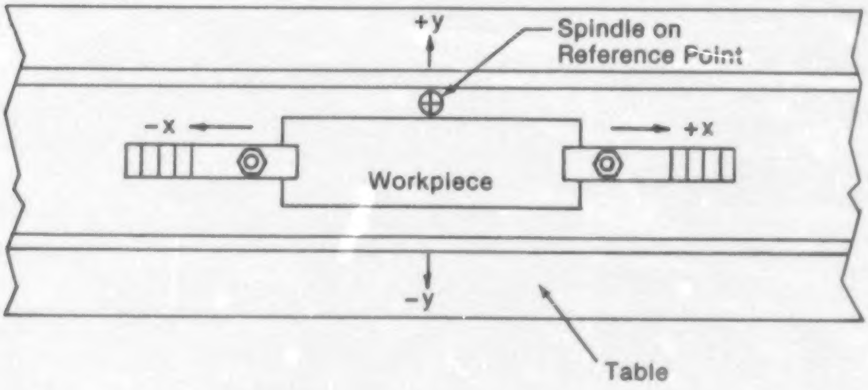
T. Raise table until there is $^3/_8$-inch space between bottom of cutter and mill table

U. Calculate and set revolutions per minute

V. Position cutter near $+x$ side of workpiece

(NOTE: Movements longitudinally [along the x axis] are referred to as $+x$ [to the right of the spindle as you face the machine] and $-x$ [to the left]. Cross travel [along the y axis] is referred to as $+y$ [to the back of the table] and $-y$ [to the front]. See Figure 53.)

FIGURE 53



JOB SHEET #8

W. Turn spindle on

X. Feed workpiece longitudinally toward +x side of cutter

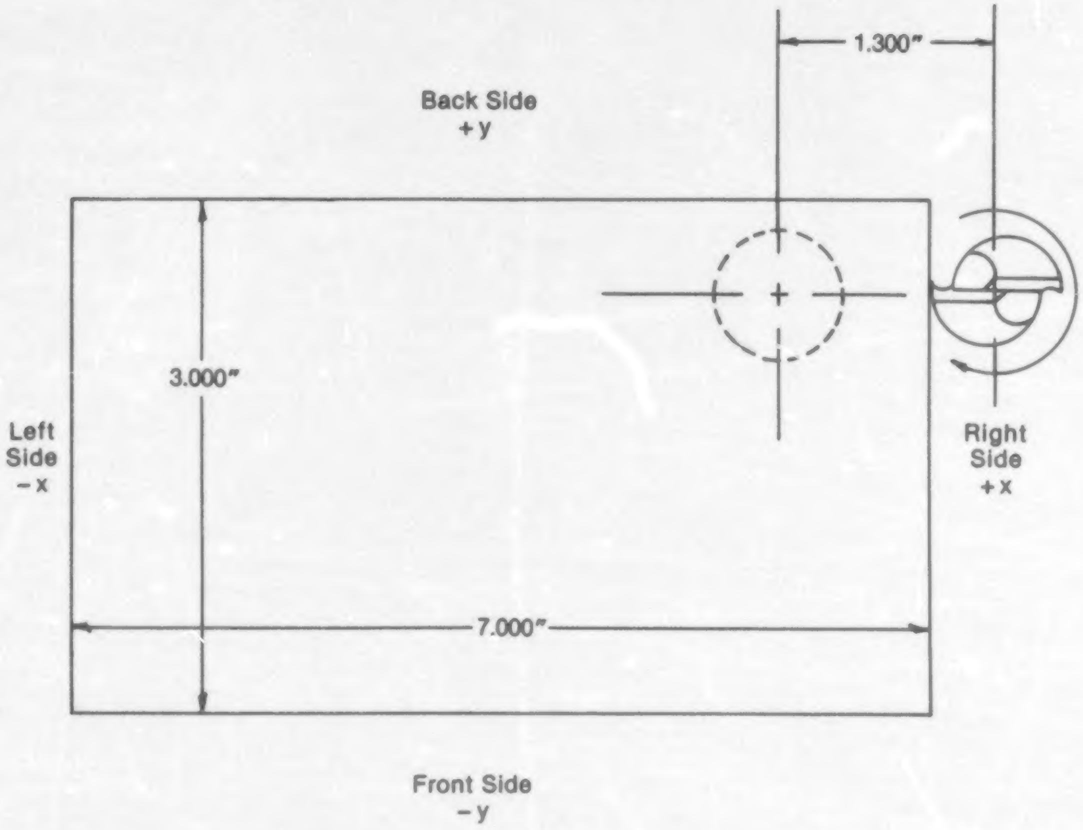
Y. Insert piece of paper between cutter and workpiece; continue to feed workpiece until cutter begins to shave paper

Z. Retract quill into housing and zero graduated collar of longitudinal feed

AA. Move table longitudinally 1.300 inches; lock table clamp (Figure 54)

(NOTE: The 1.300 inches includes 0.002 inch for the thickness of the paper.)

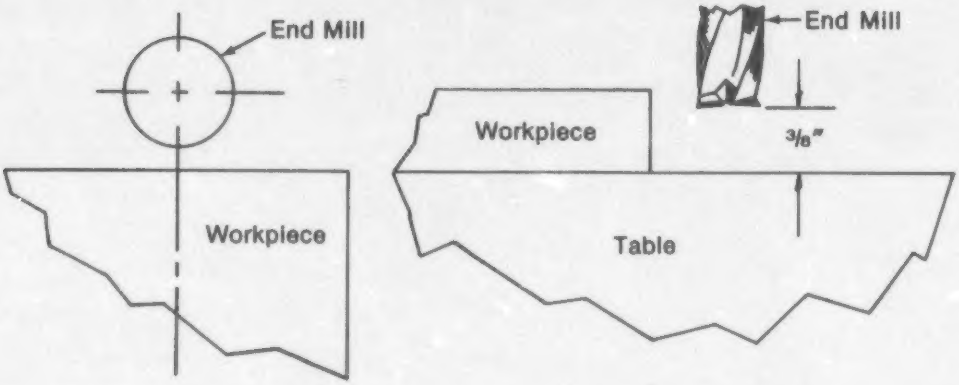
FIGURE 54


1.300"
Back Side
+y
3.000"
Left
Side
−x
Right
Side
+x
7.000"
Front Side
−y

JOB SHEET #8

BB. Turn cross-travel handcrank counterclockwise until tool is clear; then pull quill down until cutter is 3/8 inch from table (Figure 55)

FIGURE 55


End Mill
Workpiece
End Mill
Workpiece
3/8"
Table

CC. Turn cross-travel handcrank until cutter is near edge of workpiece

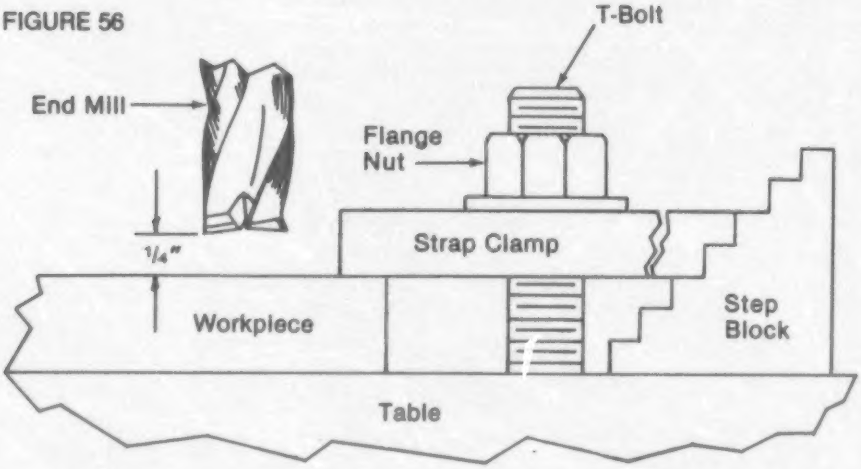
DD. Insert a strip of paper between cutter and workpiece; continue to feed workpiece toward cutter until cutter starts to shave paper

EE. Retract quill into housing, and zero graduated collar of cross travel

FF. Cross feed table 1.300 inches; lock saddle clamp (Figure 56)

GG. Lower quill so that bottom of cutter is 1/4 inch from top surface of workpiece; lock quill (Figure 56)

FIGURE 56


T-Bolt
End Mill
Flange Nut
Strap Clamp
1/4"
Workpiece
Step Block
Table

JOB SHEET #8

HH. Raise table until cutter just starts to cut top surface of workpiece; zero graduated collar elevating handcrank; start and adjust coolant

II. Raise table 0.375 inch, and snug knee lock; unlock saddle

JJ. Turn cross-travel handcrank from its present reading to move table 1.200 inches

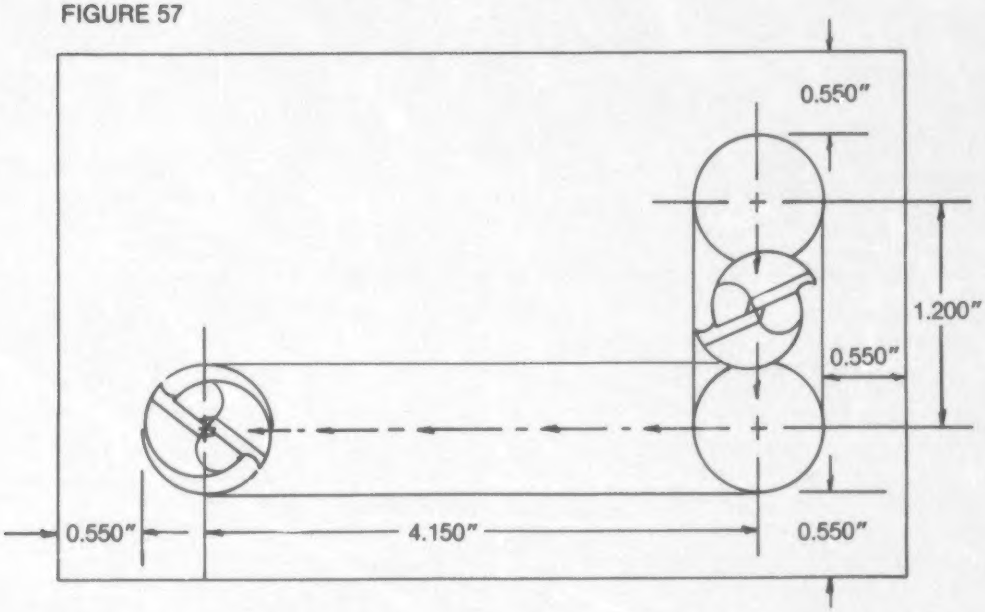
KK. Lock saddle clamp

LL. Record readings of both cross-travel and longitudinal (right-side) travel graduated collars

MM. Unlock longitudinal table clamp

NN. Use right-side handcrank to move table −*y* 4.150 inches (Figure 57)

FIGURE 57



OO. Lock table clamp, and record reading of longitudinal-feed graduated collar

PP. Unlock saddle clamp, and turn cross-travel handcrank counterclockwise until you feel the backlash removed

QQ. Crank cross-travel handcrank to move table 1.200 inches

RR. Lock saddle, and record reading of cross-travel graduated collar

JOB SHEET #8

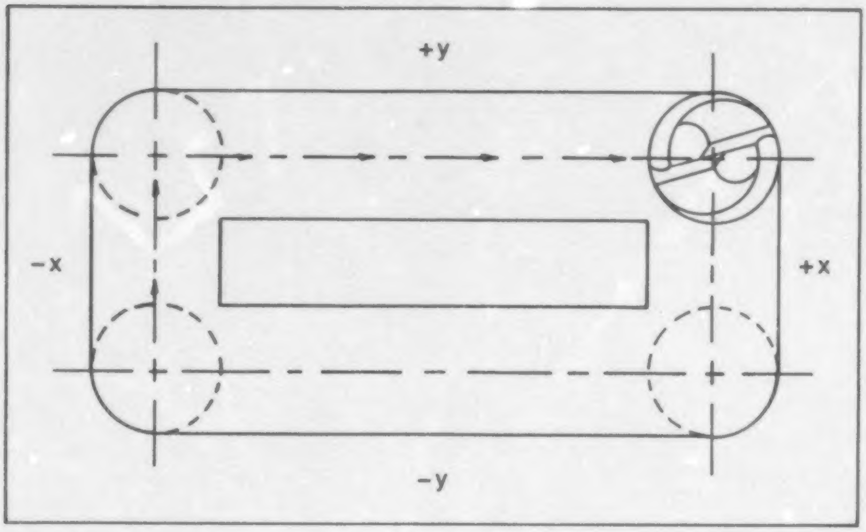
SS. Unlock table clamp, and turn right longitudinal handcrank clockwise, enough to remove slack

TT. Move table longitudinally another 5.150 inches; lock table clamp

UU. Record reading of longitudinal graduated collar

VV. Unlock saddle and turn cross-travel handcrank clockwise to dimension 62 (Figure 58)

FIGURE 58



WW. Measure wall thickness on back side (+y) and right side (+x); subtract 0.500 inch from each of these readings, and record on paper

XX. Unlock knee, and raise table 0.062 inch; lock knee

YY. Unlock the clamp, and turn right-side longitudinal crank counterclockwise to setting recorded; lock table to clamp

ZZ. Unlock saddle, and turn cross-travel handcrank counterclockwise to setting recorded plus the amount obtained from measurement; lock saddle

AAA. Unlock longitudinal table clamp, and turn right-side longitudinal handcrank clockwise to recorded setting plus amount obtained from measurement; lock table clamp

JOB SHEET #8

BBB. Unlock saddle clamp, and turn cross-travel handcrank clockwise to recorded setting

CCC. Crank cross-travel handcrank counterclockwise to move table 0.625 inch; lock saddle clamp

DDD. Crank right-side longitudinal handcrank counterclockwise to setting recorded at left-side (–x) location

EEE. Unlock quill, and move it up into housing

FFF. Unlock knee clamp, and lower table about ten turns of handcrank; stop spindle

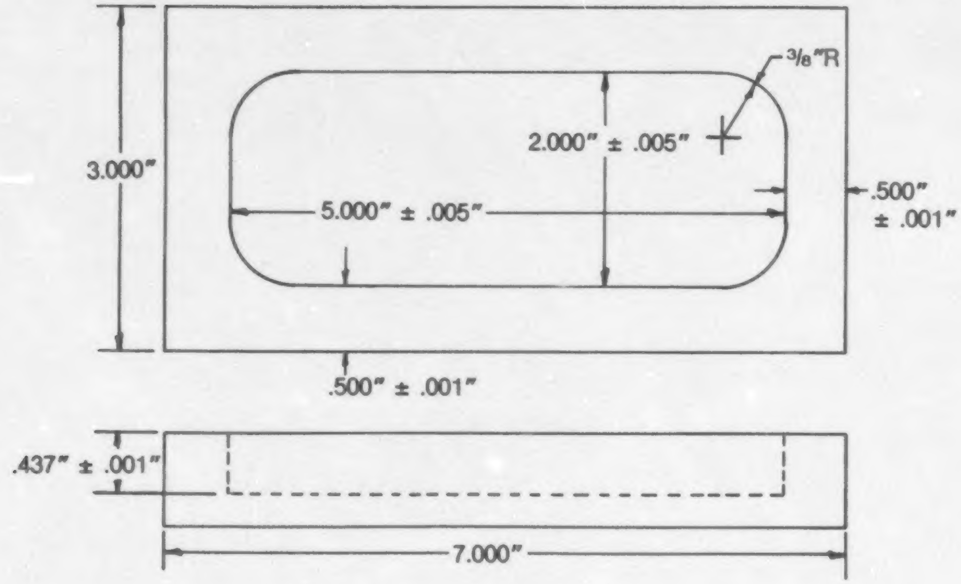
GGG. Remove and deburr workpiece

HHH. Turn in workpiece to your instructor for evaluation

III. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

EVALUATION SHEET
JOB SHEET #8


3/8"R
2.000" ± .005"
3.000"
5.000" ± .005"
.500" ± .001"
.500" ± .001"
.437" ± .001"
7.000"

	In Tolerance	Out Tolerance
+x wall .500 ± .001"		
−y wall .500 ± .001"		
Width 2.000 ± .001"		
Length 5.000 ± .005"		
Depth .437 ± .001"		

Comments ____

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #9 — PERFORM PRECISION LOCATING, DRILLING, AND REAMING OF HOLES

I. Equipment and materials

- A. Vertical mill with vise
- B. Dial indicator
- C. Edge finder with 0.200-inch end
- D. Drill chuck and wrench
- E. Combination drill and countersink (center drill), #4
- F. Reamer, 7/16 inch
- G. Drill, 27/64 inch
- H. Countersink, 3/4 inch, 82-degree
- I. File with handle
- J. Set of parallels, 1 7/8" × 1/2" × 6"
- K. Soft-faced mallet
- L. Wrenches for drawbar and vise
- M. Premachined steel SAE 1095 blocks, 1.020" × 2.020" × 3.020"
- N. Cutting oil in pump can
- O. Parallel, 1" × 3" × 6"

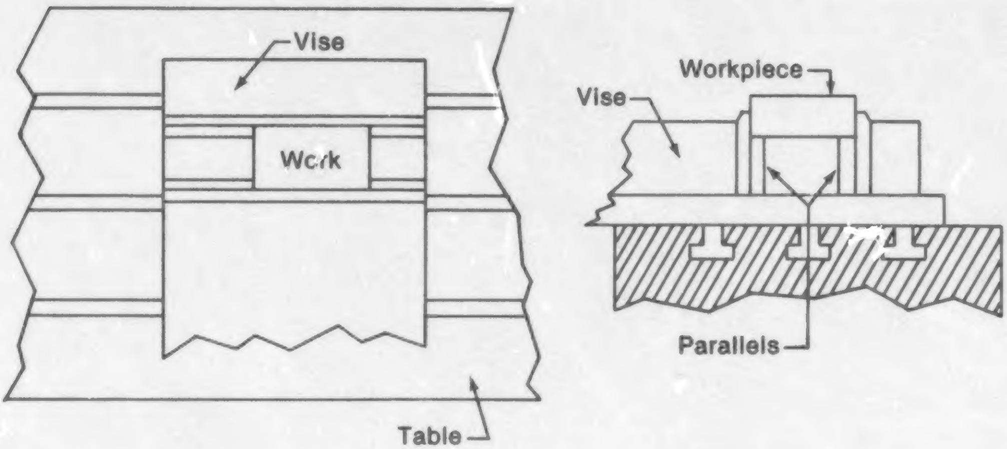
II. Procedure

- A. Perform daily maintenance procedures
- B. Align head square to table
- C. Align vise parallel to T-slot
- D. Clean vise, and place parallels in vise opening

JOB SHEET #9

E. Place workpiece in vise so that 2.020-by-3.020-inch surface is up; seat firmly on parallels (Figure 59)

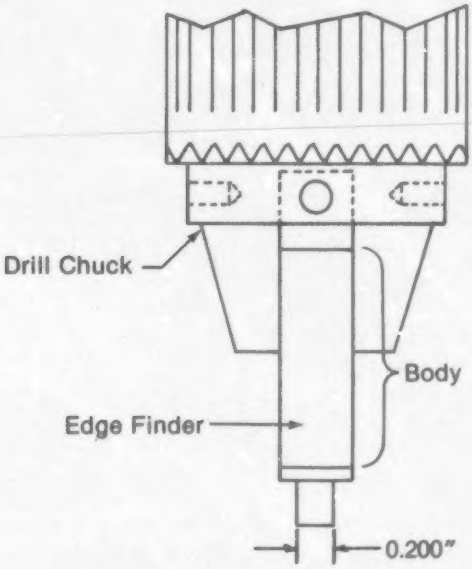
FIGURE 59


Vise
Work
Table
Workpiece
Vise
Parallels

F. Put drill chuck in spindle and secure drawbar

G. Place body of edge finder in drill chuck and secure (Figure 60)

FIGURE 60

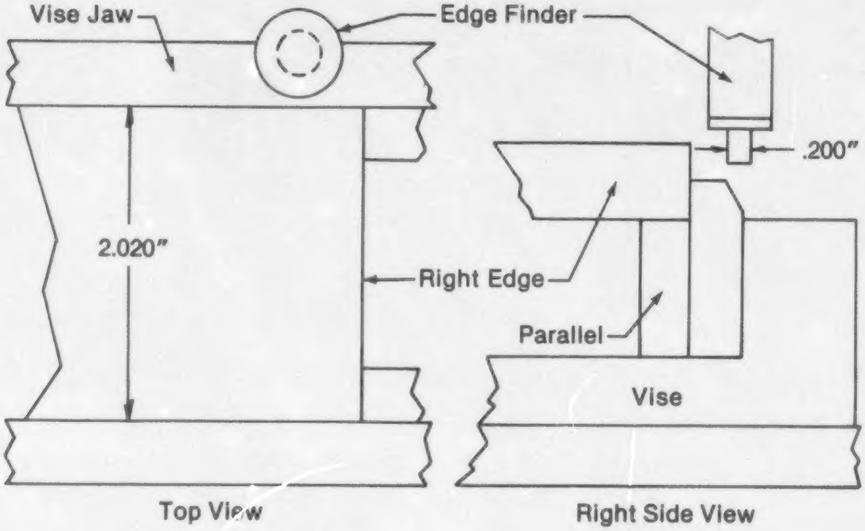

Drill Chuck
Body
Edge Finder
0.200"

JOB SHEET #9

H. Set spindle speed at 600 rpm, and start spindle (clockwise rotation)

I. Lower quill about 3 inches; raise knee so that 0.200-inch end of edge finder is 1/8 inch below top surface of workpiece at back edge and about 1/2 inch from right end (Figure 61)

FIGURE 61

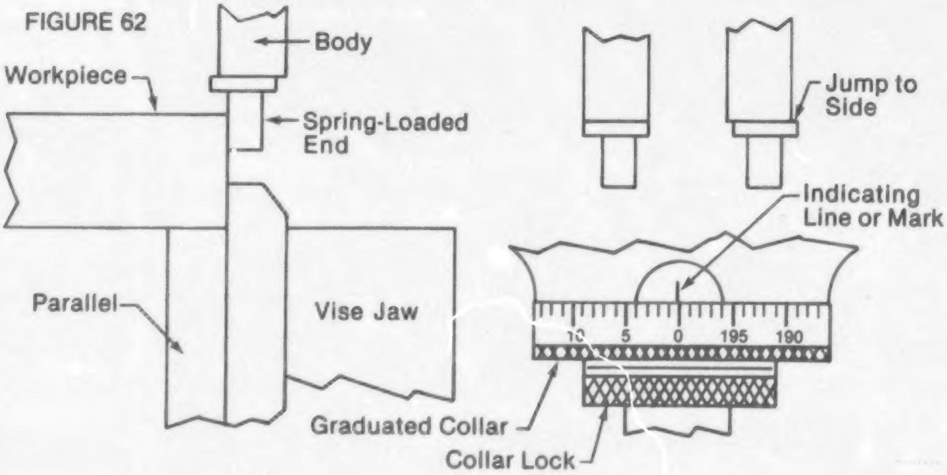

Vise Jaw
Edge Finder
2.020"
Right Edge
.200"
Parallel
Vise
Top View
Right Side View

J. Loosen cross-travel handcrank graduated collar, and use cross travel to move workpiece toward spring-loaded end of edge finder

K. Continue to turn handcrank until bottom of edge finder jumps to side

L. Set graduated collar so that zero line is the width of the line past indicating mark (Figure 62)

FIGURE 62


Body
Workpiece
Spring-Loaded End
Jump to Side
Indicating Line or Mark
Parallel
Vise Jaw
10
5
0
195
190
Graduated Collar
Collar Lock

JOB SHEET #9

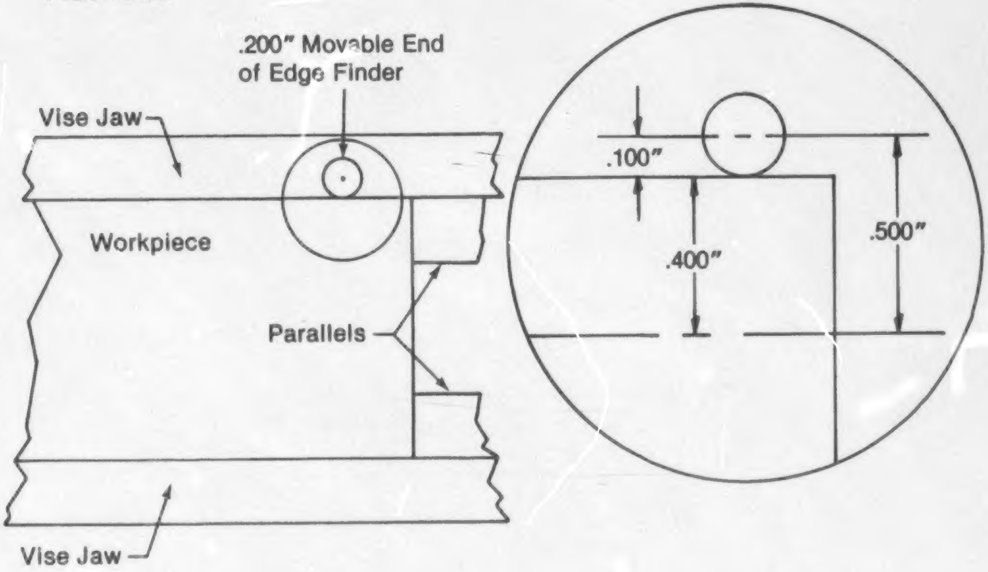
M. Move workpiece from edge finder; then slowly feed workpiece back to edge finder

(NOTE: As the dial on the graduated collar reaches zero, the spring-loaded end should move to the side as before.)

N. Raise quill; crank cross-travel handcrank clockwise to move table 0.500 inch (Figure 63)

(NOTE: The 0.500-inch distance includes 0.100 inch to put the center of the spindle at the edge of the workpiece.)

FIGURE 63



O. Lock saddle clamp, and position edge finder near right side of workpiece

P. Pull quill down so that movable end is 1/8 inch below surface of workpiece

Q. Repeat steps J through M

R. Raise quill, and move table longitudinally 0.464 inch; lock table

S. Remove edge finder from chuck

T. Place center drill in drill chuck, and tighten chuck

JOB SHEET #9

U. Set speed at 800 rpm; center drill workpiece

V. Remove center drill; chuck $^{27}/_{64}$-inch drill in chuck

W. Set speed at 411 rpm, and drill a $^{27}/_{64}$-inch hole through workpiece; apply cutting fluid as required

X. Remove drill; chuck a $^{7}/_{16}$-inch reamer in drill chuck

Y. Set speed to 205 rpm, and ream workpiece; apply cutting fluid as required

Z. Unlock table clamp, and move table 1.145 inch; lock table

AA. Repeat steps T through Y to drill and ream second hole

BB. Unlock table clamp, and move table to center third-hole location under spindle

CC. Repeat steps T through Y to drill and ream third hole

DD. Crank table back to location of first hole

(CAUTION: Feed the table past the setting, and then crank it back to remove backlash.)

EE. Unlock saddle, and feed cross travel 1.217 inch; lock saddle and table

FF. Repeat steps T through Y at this location

GG. Unlock table, and feed table 1.145 inch; lock table

HH. Repeat steps T through Y at this location

II. Unlock table, and feed table 1.145 inch; lock table

JJ. Repeat steps T through Y at this location

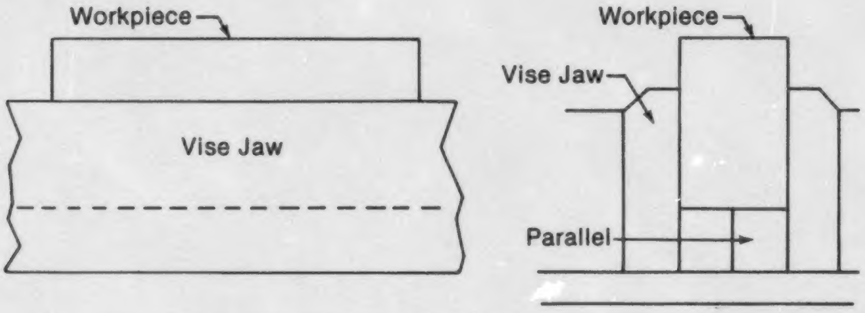
KK. Remove workpiece from vise, and remove parallels

LL. Set 1″ × 3″ × 6″ parallel in vise opening, and set workpiece in opening with 3.020-inch surface on parallel

JOB SHEET #9

MM. Tighten vise and seat workpiece (Figure 64)

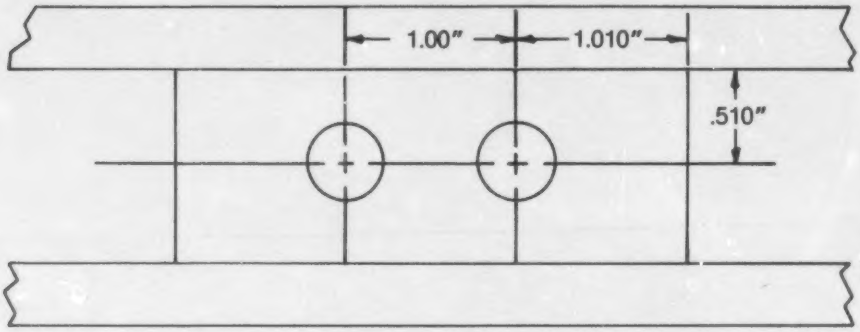
FIGURE 64


Workpiece
Vise Jaw
Workpiece
Vise Jaw
Parallel

NN. Use edge finder to position workpiece and center drill; drill and ream holes as indicated (Figure 65)

(CAUTION: Make sure that speed is set correctly for each of the operations. Remove parallel before drilling holes.)

FIGURE 65

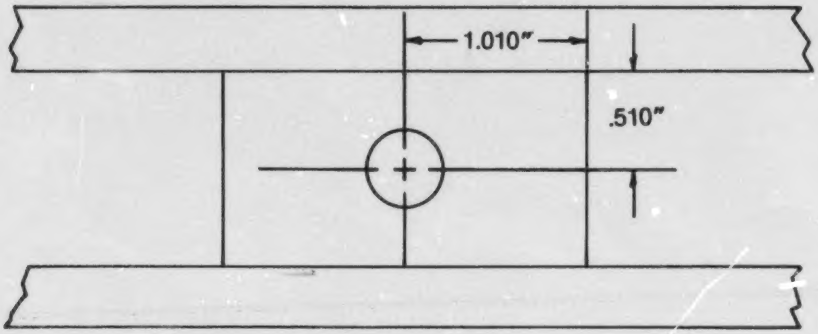

1.00"
1.010"
.510"

OO. Remove workpiece, and stand workpiece on parallel with end to be drilled up

JOB SHEET #9

PP. Locate, drill, and ream hole (Figure 66)

FIGURE 66



QQ. Insert countersink in drill chuck and secure

RR. Open vise about $2^{1}/_{2}$ inches

SS. Place workpiece flat on bottom of vise with 2.020-inch side up

TT. Start spindle, and set speed to 100 rpm

UU. Center countersink over hole

VV. Lower quill; countersink hole with a $^{1}/_{32}$-inch chamfer; check countersink frequently to make sure of correct depth

WW. Set quill stop at correct depth

XX. Turn workpiece over, and countersink holes on other side; remove workpiece

YY. Close vise opening to $1^{1}/_{2}$ inches, and set workpiece on 1.020-inch side in vise

ZZ. Repeat steps TT through XX to countersink holes on each side

AAA. Set workpiece on end in vise

BBB. Repeat steps TT through XX to countersink holes in each end

CCC. Stop machine, and remove workpiece

DDD. Turn in workpiece to instructor for evaluation

EEE. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #10 — ALIGN A BORE CONCENTRIC TO THE SPINDLE

I. Equipment and materials

A. Vertical mill

B. Dial test indicator

C. Drill chuck with key

D. Two strap clamps and step blocks

E. T-nuts, flange nuts, and stud bolts, 6 inches (2 each)

F. Clean shop rag

G. Wrenches for drawbar, head, and flange nuts

H. Steel pipe faced 4¼ inches long, 4 inches with 3-inch OD bore

I. Steel rule, 6 inches

II. Procedures

A. Perform daily maintenance procedures

B. Align head square to table

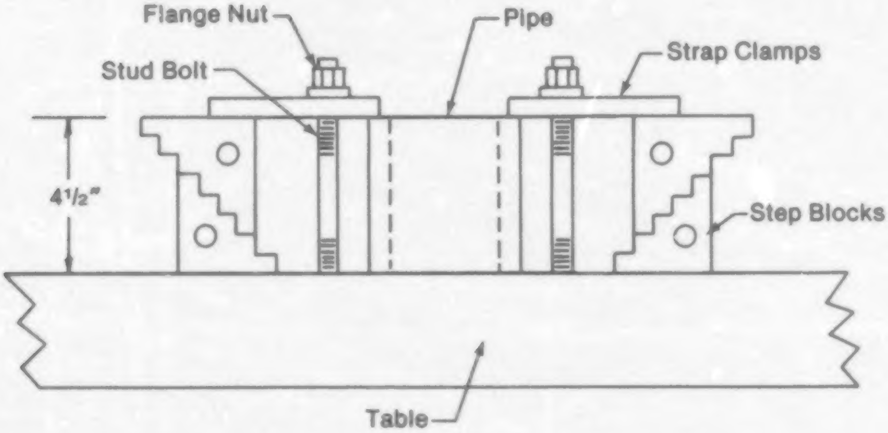
C. Place workpiece in middle of table, centered over T-slot

D. Slide T-nuts into T-slot to ¾ inch each side of workpiece; screw stud bolts into T-nuts

JOB SHEET #10

E. Adjust step blocks to 4½ inches, or slightly higher than workpiece, to place strap clamps over stud bolts with one end of clamp on workpiece and other end on step block; screw on flange nuts (Figure 67)

FIGURE 67


Flange Nut
Pipe
Strap Clamps
Stud Bolt
4½"
Step Blocks
Table

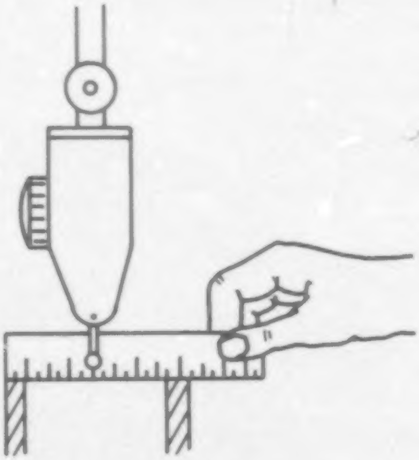
F. Place drill chuck in spindle and secure

G. Place indicator in drill chuck with indicator and point aligned with spindle; secure

H. Lower quill by hand until indicator point is in bore of workpiece

I. Use steel rule to position indicator in approximate center of bore (Figure 68)

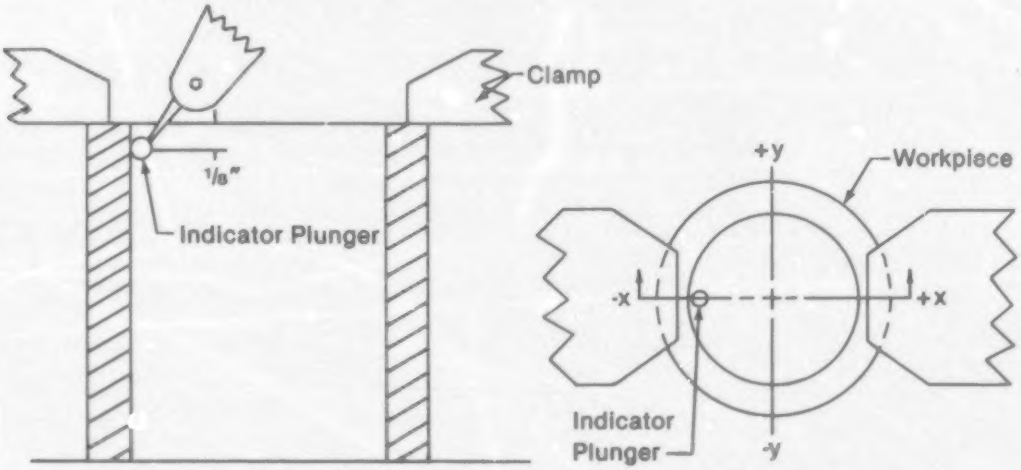
FIGURE 68



JOB SHEET #10

J. Adjust indicator swivel so that pointer touches inside wall of workpiece at $-x$ axis position; raise or lower quill so that pointer is $1/8$ inch from top of workpiece (Figure 69)

FIGURE 69


Clamp
1/8"
Indicator Plunger
+y
Workpiece
-x
+x
Indicator Plunger
-y

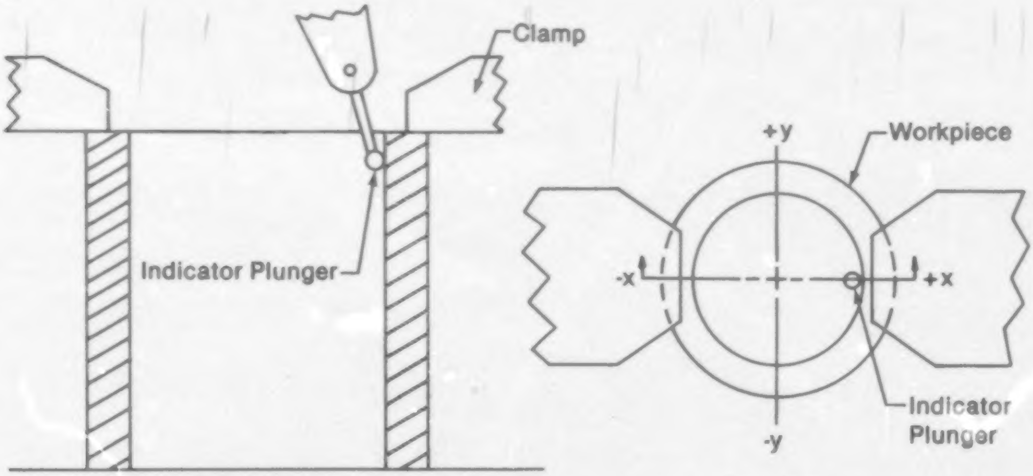
Front View

Top View

K. Adjust indicator so that pointer is almost perpendicular to table with a load of 0.010 inch; zero indicator

L. Rotate indicator clockwise 180 degrees to the $+x$ side; note indicator reading (Figure 70)

FIGURE 70


Clamp
Indicator Plunger
+y
Workpiece
-x
+x
Indicator Plunger
-y

Front View

Top View

JOB SHEET #[illegible]

M. Turn longitudinal-feed handcrank to move table until indicator needle has moved one-half distance back to zero

EXAMPLE: 0 to +0.008, move to +0.004
or
0 to −0.008, move to −0.004

N. Rotate indicator to −*y* position and repeat steps M through O for *y* axis

O. Check alignment by rotating indicator 360 degrees; pause each 90 degrees to observe indicator reading; adjust cross travel and/or longitudinal feed if necessary

P. Lock table, and have instructor check aligmment

Q. Tear down setup; clean and put away tools

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #11 — PERFORM A BORING OPERATION

I. Equipment and materials

   A. Vertical mill

   B. Adjustable boring head with wrenches

   C. Dial indicator and test indicator with attachments

   D. Inside micrometer set

   E. Clean shop rag

   F. Wrenches for vise and drawbar

   G. T-nuts, flange nuts, and stud bolts, 6 inches

   H. Steel pipe faced 4½ inches long, 4-inch OD, with 3-inch ID bore

   I. Strap clamps and step blocks

   J. Parallel, ½" × 1" × 6"

II. Procedures

   A. Perform daily maintenance procedures

   B. Align head square to table

   C. Place workpiece in middle of table, centered over T-slot

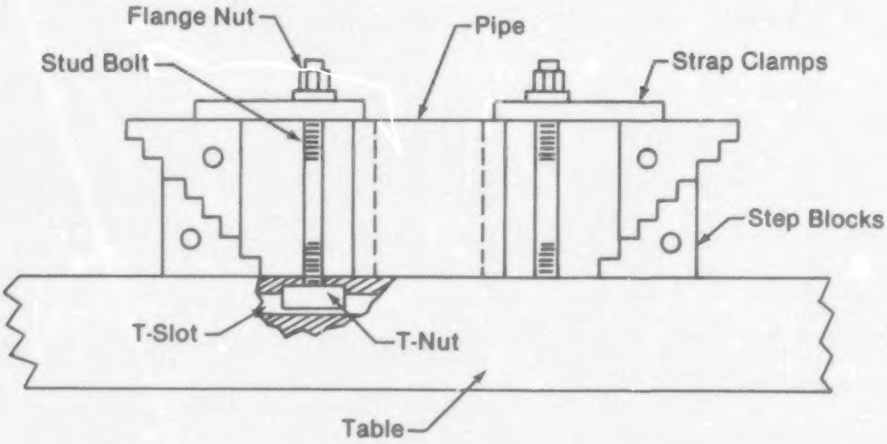
   D. Slide T-nuts into T-slots to ¾ inch each side of workpiece; screw stud bolts into T-nuts

   E. Adjust step blocks to 4½-inch height

JOB SHEET #11

F. Place strap clamps on edge of workpiece, and screw on flange nuts (Figure 71)

FIGURE 71



G. Use dial indicator to align spindle to bore

H. Lock table and saddle clamps

I. Remove indicator and drill chuck; lower table

J. Place boring head in spindle and secure

K. Place boring bar in boring head and secure

L. Set spindle speed at 120 rpm

M. Engage power-feed transmission engagement crank, and set quill feed to 0.003 inch per revolution

N. Lower knee 4 inches, and pull quill down 3 inches

O Adjust micrometer adjusting nut to quill stop and tighten locknut

P. Lay parallel across top surface of workpiece, and place a piece of paper between cutter and parallel

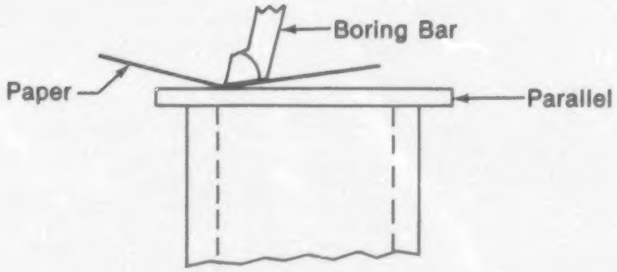
Q. Crank up knee until cutter makes contact with paper; zero graduated collar of elevating crank

JOB SHEET #11

R. Raise quill and table 2.500 inches; lock knee (Figure 72)

(CAUTION: Take care when raising table not to apply any pressure to the carbide tip of the boring bar because it will chip.)

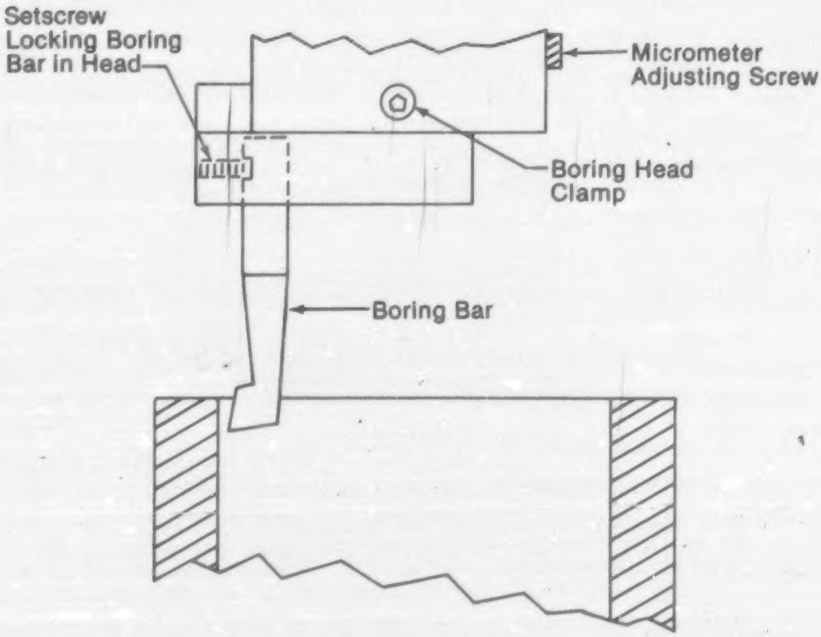
FIGURE 72


Boring Bar
Paper
Parallel

S. Pull quill down so that boring bar is 1/4 inch below top surface of workpiece

T. Loosen clamp of boring head, and adjust head out until cutter is almost to edge of bore (Figure 73)

FIGURE 73


Setscrew Locking Boring Bar in Head
Micrometer Adjusting Screw
Boring Head Clamp
Boring Bar

JOB SHEET #11

U. Retract quill into housing, and move boring head out 0.025 inch; tighten boring head clamp

V. Pull boring bar to within 1/8 inch of surface of workpiece; start spindle

W. Engage quill power feed, and allow boring head to feed into bore until it reaches stop

X. Raise quill, and stop spindle

Y. Use inside micrometer to determine total amount of material that must be removed

Z. Loosen clamp, and adjust boring head out a maximum of 0.050 inch to correct bore diameter

(NOTE: If boring head micrometer adjusting screw is calibrated 1:2, maximum feed should be 0.025 inch.)

AA. Adjust boring head to within 0.010 inch of finish diameter, and make last rough cut

BB. Adjust boring head out 0.010 inch more; increase speed to 150 rpm, and make finish cut

CC. Stop spindle, and check ID; if additional material needs to be removed from bore, make adjustments, and repeat procedure as required

DD. Remove workpiece; turn in workpiece to instructor for evaluation

EE. Tear down setup; clean and put away all tools

VERTICAL MILLING MACHINES
UNIT III

JOB SHEET #12 — PERFORM DRILLING AND MILLING OPERATIONS USING DIVIDING HEAD

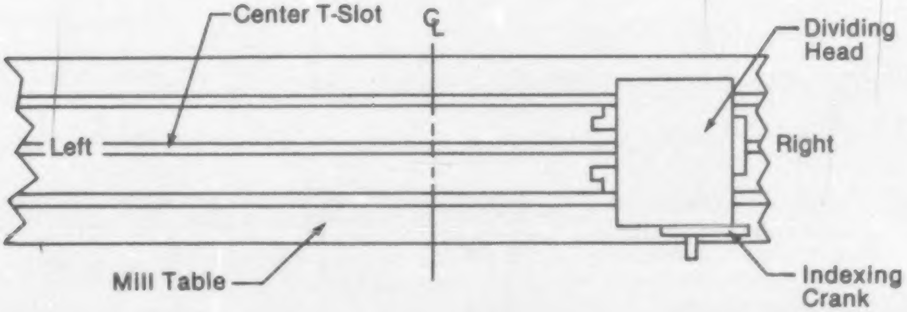
I. Equipment and materials

- A. Vertical-type mill
- B. Dividing head with three plates or one reversible plate, footstock, three-jaw chuck, and hold-down bolts
- C. Dial indicator with attachments
- D. Drill chuck
- E. End mill holder, 3/8 inch
- F. Center drill, #3
- G. Two-flute end mill, 3/16 inch
- H. Drill, 5/16 inch
- I. Steel SAE 1018 bar, 5 inches long, turned to 1.072-inch diameter and center drilled on one end
- J. Edge finder
- K. Soft-faced mallet
- L. Clean shop rag

II. Procedure to drill two holes 90 degrees to each other using direct indexing

- A. Perform daily maintenance procedures
- B. Clean table, and mount dividing head right of center with chuck facing left (Figure 74)

FIGURE 74



JOB SHEET #12

C. Slide T-bolts into center slot, and snug dividing head to mill table

(NOTE: The alignment lugs on the dividing head align the head square to the table.)

D. Secure workpiece in chuck with center-drilled end protruding 4 inches from chuck jaws

E. Put drill chuck in spindle of mill and secure

F. Loosen bolts that allow dividing head to be swiveled up and down

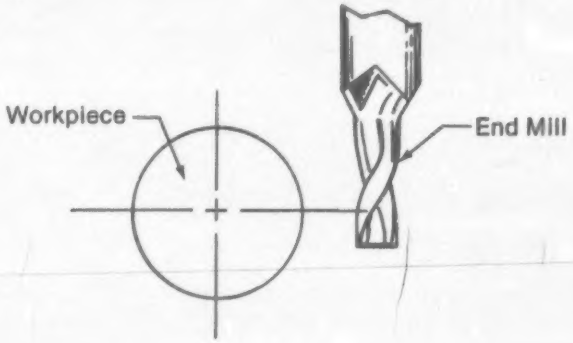
G. Place dial indicator to drill chuck so that plunger of indicator is over workpiece; align workpiece

H. Tighten securing bolts, and remove indicator

I. Mount footstock to table with center in hole of workpiece; secure

J. Place edge finder in drill chuck with 1/2-inch end protruding from chuck; bring edge finder down so that spring-loaded end is centered on workpiece (Figure 75)

FIGURE 75



K. Turn on spindle, and set speed for 100 rpm

L. Move workpiece toward edge finder until spring-loaded end moves to side; zero cross-travel graduated collar

M. Raise edge finder so that bottom clears top surface of workpiece

N. Crank cross-travel handcrank to feed workpiece toward edge finder a distance equal to one-half diameter of workpiece plus one-half diameter of edge finder

O. Crank table longitudinally until edge finder clears end of workpiece

JOB SHEET #12

P. Locate end of workpiece with edge finder; zero graduated collar

Q. Raise spindle, and move table 3.250 inches

(NOTE: The center of the spindle should be 3 inches from end of workpiece.)

R. Remove edge finder from chuck, and secure center drill in chuck

S. Calculate number of indexing holes required to rotate workpiece 90 degrees

T. Set dividing head in position so that chuck can be rotated by hand

1. Turn worm gear engagement knob
2. Lift direct-indicating plunger
3. Unlock spindle lock
4. Check to see that chuck will rotate freely

U. Turn chuck until required hole is at top, place indexing plunger in hole, and tighten spindle lock

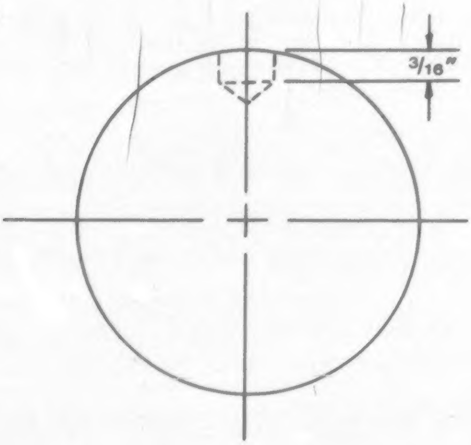
V. Start spindle, and set speed at 1,500 rpm

W. Center drill 1/32 inch past drill portion of center drill

X. Remove center drill, and secure 5/16-inch drill in chuck

Y. Drill hole 3/16 inch deep (Figure 76)

FIGURE 76



JOB SHEET #12

Z. Remove drill; replace with center drill

AA. Reset indexing plate to required hole to rotate workpiece 90 degrees

BB. Center drill, and drill second hole

CC. Remove drill and drill chuck

III. Procedure to mill nine equally spaced slots using simple indexing

A. Put end mill holder in spindle and secure; secure end mill in holder

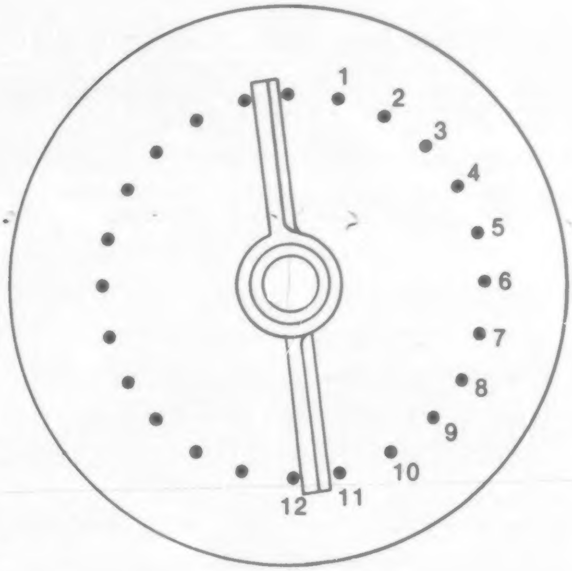
B. Calculate indexing required by dividing number of divisions into ratio of dividing head

C. Put required plate on dividing head

D. Move sector arm to required hole and tighten (Figure 77)

(NOTE: Do not count the hole the pin is in.)

FIGURE 77

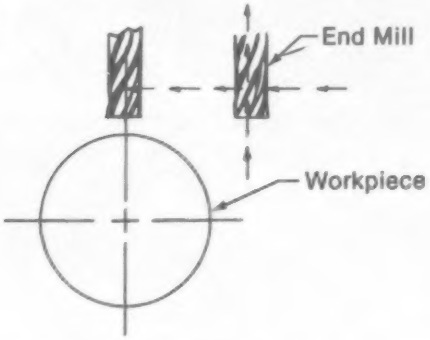


JOB SHEET #12

E. Center work using cutter

1. Turn on spindle, and set speed to 2,000 rpm
2. Lower spindle so that cutter is centered at back side of workpiece
3. Place piece of paper between workpiece and cutter; slowly crank workpiece toward cutter until it starts to shave paper
4. Raise cutter clear of top of workpiece; zero graduated collar on cross travel
5. Move table under spindle a distance equal to one-half diameter of workpiece plus one-half diameter of cutter and 0.002 inch to allow for thickness of paper (Figure 78)

FIGURE 78



F. Raise table until cutter starts to cut top surface of workpiece; zero elevating graduated collar

G. Crank longitudinal-feed handcrank to move workpiece so that cutter clears end of workpiece

H. Raise table 0.187 inch

I. Advance longitudinal feed until cutter reaches end of workpiece; zero longitudinal graduated collar

J. Feed table longitudinally 2.500 inches, and then crank in opposite direction until cutter clears workpiece

K. Set indexing head for next cut

(NOTE: The indexing head is set to index after each cut is completed.)

L. Feed table longitudinally to place workpiece at starting point 2.5 inches from end of workpiece

JOB SHEET #12

M. Repeat steps J through L until all nine slots have been cut

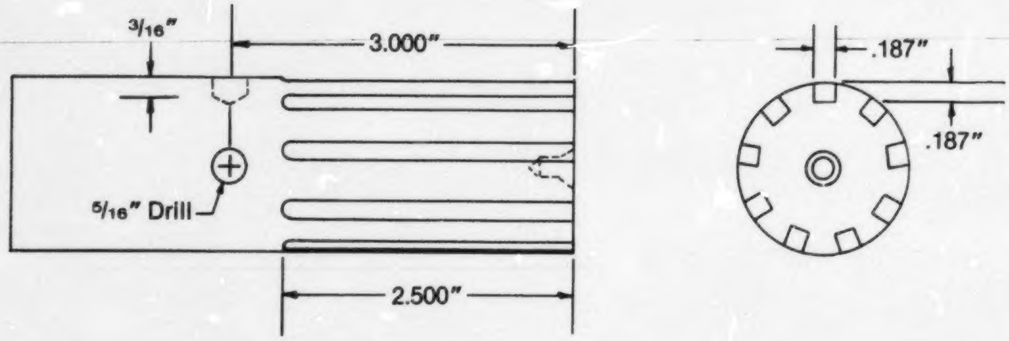
N. Stop spindle, and remove workpiece

O. Deburr workpiece; turn in workpiece to instructor for evaluation

P. Tear down setup; clean and put away all tools

VERTICAL MILLING MACHINES
UNIT III

EVALUATION SHEET
JOB SHEET #12


3/16"
3.000"
5/16" Drill
2.500"
.187"
.187"

	YES	NO
Drilled holes 5/16" × 3/16" deep		
Holes 90 degrees to each other		
Slots spaced properly		
Slots 3/16" × 3/16" deep		
Slots proper length		
Hole in center		
Slots centered properly		
Work deburred		

Comments ____

____

____

____

____

VERTICAL MILLING MACHINES
UNIT III

TEST

NAME ______________________________________ SCORE ________________

1. Match to their correct definitions terms associated with vertical milling machines. Write the correct numbers in the blanks.

_____a. Hardened-steel sleeve with threads on one end used to hold standard-diameter tool shanks

_____b. Device installed in spindle that provides for quickly securing or removing cutting tools by turning a spring-loaded cam

_____c. Clockwise or counterclockwise direction of spindle rotation

_____d. Movement of chips away from cutter and workpiece; caused by use of cutting fluid

_____e. Deviations from a perfect plain surface caused by cutting action

_____f. Final cut to a surface to obtain desired smoothness

_____g. Work-holding device mounted to milling machine with chuck in vertical or horizontal position; designed to be used with indexing plate by moving in uniform increments for rapid indexing

1. Spindle direction
2. Finish cut
3. Collet
4. Chip flow
5. Super spacer
6. Cam-lock adapter
7. Teeth marks

2. Identify vertical milling operations. Write the correct names in the blanks.

End milling
Side end milling
Slotting
Drilling or reaming holes
Boring
Pocket milling
Squaring
Milling key slots and key seats
Indexing
Angular milling
Fly-cutting

a. ______________________________ — Milling a surface parallel to axis of spindle by using periphery of end mill or shell mill cutter

b. ______________________________ — Using a single-point tool to enlarge a hole by means of an adjustable head

TEST

c. ______________________________ — Producing a large flat surface 90 degrees to axis of spindle with cutter or cutters mounted to a holder

d. ______________________________ — Milling a surface at 90 degrees to axis of spindle to using a solid-shank cutting tool or an adapter-held shell end mill

e. ______________________________ — Producing or finishing holes that require precise locations

f. ______________________________ — Producing a recess with a flat bottom and straight sides

g. ______________________________ — Cutting a recess with a flat bottom and straight walls, or flat bottom and straight walls joined with a fillet

h. ______________________________ — Rotating workpiece a specific fractional amount of a turn to perform repeated milling operations

i. ______________________________ — Cutting slots to receive keys

j. ______________________________ — Cutting surfaces of a workpiece at 90-degree angles to each other

k. ______________________________ — Milling an angle on a workpiece with reference to a designated surface

(NOTE: Test question 3 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

3. Demonstrate the ability to

   a. Mount and remove cutters and cutter holders for vertical spindle machines.

   b. Use machine controls properly.

   c. Mount and align vise.

   d. Align head square to table.

   e. Perform a side milling operation.

   f. Perform an end milling operation.

   g. Mill a key seat with keyseat cutter and a key slot with end mill.

TEST

h. Mill a rectangular pocket.

i. Perform precision locating, drilling, and reaming of holes.

j. Align a bore concentric to the spindle.

k. Perform a boring operation.

l. Perform drilling and milling operations using dividing head.

VERTICAL MILLING MACHINES
UNIT III

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 1
   d. 4
   e. 7
   f. 2
   g. 5

2. a. Side end milling
   b. Boring
   c. Fly-cutting
   d. End milling
   e. Drilling or reaming holes
   f. Slotting
   g. Pocket milling
   h. Indexing
   i. Milling key slots and key seats
   j. Squaring
   k. Angular milling

3. Performance skills evaluated to the satisfaction of the instructor